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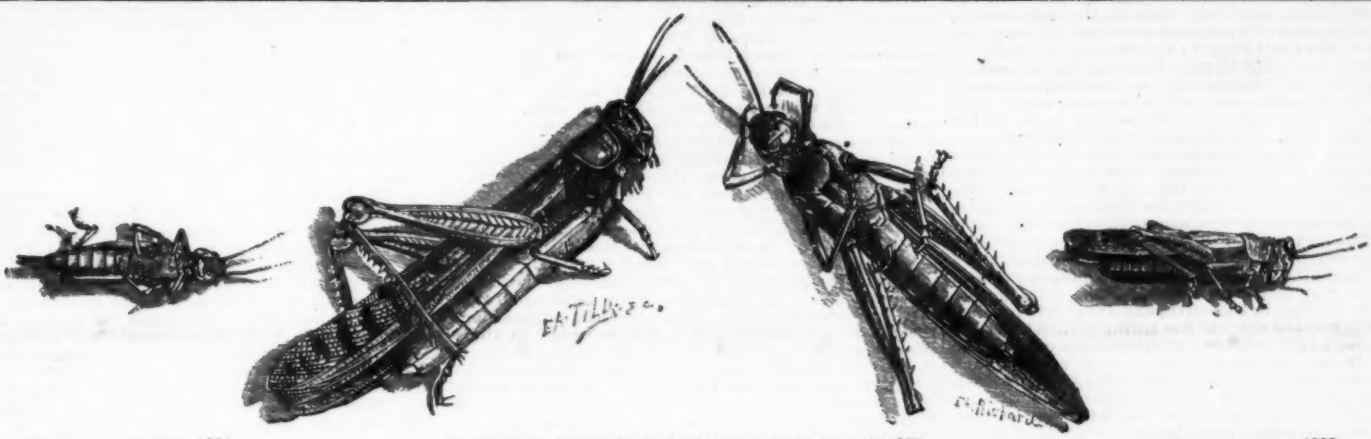
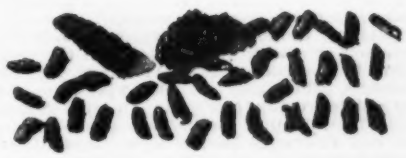


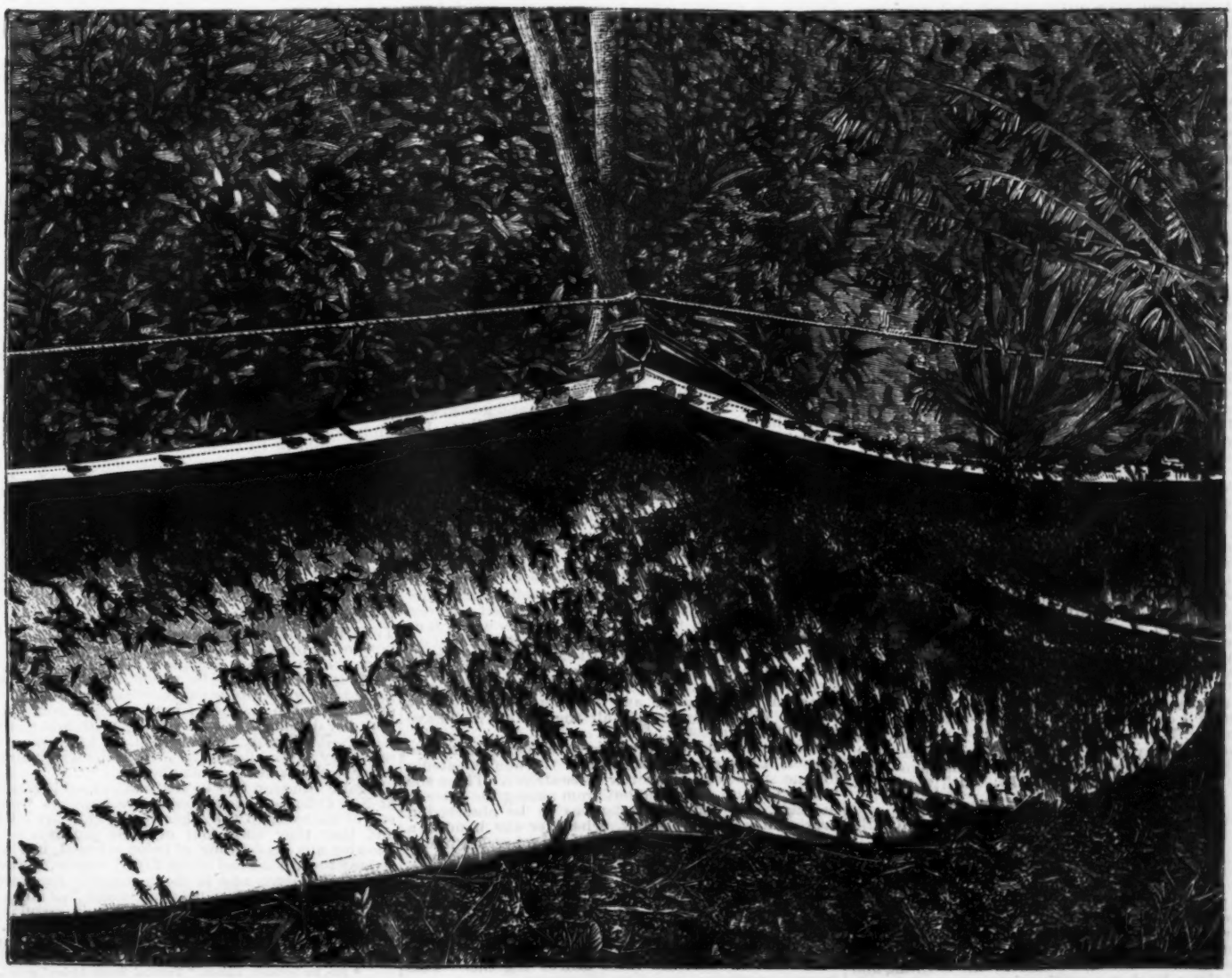
WINGED CRICKET, 1888. WINGED CRICKETS (STAURONOTUS MAROCCANUS), 1887. WINGED CRICKET, 1888.

CASES OF HARD MUCILAGE IN WHICH THE CLUSTERS OF EGGS ARE LAID BY THE INSECT.

NEWLY HATCHED CRICKETS, THREE DAYS OLD, 1889.



EGGS TAKEN OUT OF THE CASES IN WHICH THEY ARE LAID BY THE INSECT.



THE PLAGUE OF CRICKETS IN ALGERIA—APPARATUS OF A CLOTH SCREEN PUT UP TO STOP THE CRICKETS.

THE PLAGUE OF CRICKETS IN ALGERIA.

THE immense ravages of all the growing crops of grain by a peculiar species of cricket, the *Stauronotus Maroccanus*, which infests the eastern provinces of Algeria, were minutely described and illustrated in this journal on August 4, 1888. This destructive insect, bred on the dry and bare highlands of the Teli, has been descending into the cultivated plains, toward the shores of the Mediterranean, during the past four years. Its shape and size, when full grown, are correctly represented in the pair shown (the largest of those in our illustrations) by the engravings in this number. Its color is russet or reddish brown. The insect's mouth is armed with two strong horny hooks in the upper jaw, moving horizontally, crossing each other like the blades of scissors. With these, having climbed a cornstalk, they first quickly strip off the beard and husks of the ear of corn, which they allow to fall to the ground; and then cut open every grain, devouring only its farinaceous part, and this to the last crumb. Five or six insects will ascend a cornstalk at once, till it bends under their weight; millions and millions are in the field, swarming all round, seeking an unoccupied stalk, for they will seldom eat the husks or the stalk itself. The female insect, which is much larger than the male, lays her eggs about the end of June or the beginning of July. She chooses dry and sterile ground, in which she bores a hole, an inch deep, by the instrumentality of a valvular sucking tube at the extremity of her abdomen. Applying the end of this tube to the grains of earth or sand, which are loosened by its moisture, she lifts and removes them sticking to the tube, and continues the process till the hole is excavated. Then she deposits in the hole a cylindrical ovary, a case or shell of hardened mucilage, containing about forty eggs, very neatly packed together. The eggs remain nine months in the earth, and are slowly hatched by the heat of the sun, till the spring of the following year, when a little white caterpillar comes out of each egg; it is speedily transformed into a cricket; and these insects, collecting rapidly over spaces of hundreds of miles, form vast and terrible armies, which begin their march as creeping things, but are presently furnished with wings as they attain the full size of adults, while they proceed in their devastating advance, guided by some mysterious instinctive knowledge, to the corn-growing regions far distant from the land of their birth.

The French government of Algeria last year commenced an extensive system of preventive or defensive operations against this enormous mischief. A scientific and practical commission, of which M. Künckel d'Herculais was president, was charged with the task, and resolved to adopt measures both for destroying the young crickets, before they get their wings, and for collecting and destroying their eggs. An exact geographical survey and map of the districts where the insects had laid their eggs having been prepared, the Arab tribes were summoned to form encampments in those districts; and remuneration was promised to them, for gathering the eggs, at the rate of 1f. 50c. for the quantity of two décalitres, which is more than two pecks of English measure. This work continued from August to December last year, the total sum paid for it being nearly 600,000f.; but it did not suffice to prevent the reappearance of the living crickets, in somewhat diminished numbers, in the spring of the present year. The government commission then resorted to the plan which was successfully employed in Cyprus, a few years ago, by the British administrative authorities there, against the plague of locusts. It is that of fixing up long bands of cotton cloth or calico, supported by sticks, and stretching as a fence, in some cases, across one mile or more of the country, to intercept the march of the yet unwinged insects; and also digging a trench in front of the barrier, so that the insects fall back into the trench when they fail to climb to the top of the cloth, and cannot afterward escape. Our illustrations show the appearance of these fences and trenches, of which nearly six thousand have been constructed at the expense of the French government. The cloth stands about 2 ft. high; its lower edge is fixed close to the ground, and its upper edge has a slippery border of waxed cloth, nearly four inches wide, kept moist by daily oiling. The insects cannot keep their hold on this oiled border, and inevitably drop back into the trench beneath, which is 3 ft. 8 in. deep, and of the same width, and the sides of which are lined with plates of zinc. After about twenty-five minutes, the host of crickets still pressing on to the barrier, over spaces left purposely between the lengths of the trenches, each of which is only 7 ft. or 8 ft. long, all the trenches are full of masses of struggling insects. They are constantly watched by the Arabs, one of whom jumps into the trench, as soon as he sees it filled, and trampies them to death with his feet, while he thrashes the living mass with a heavy stick, or log of wood, till they are all dead and reduced to a hideous pulp, which is immediately dug out and carried away, leaving the trench empty to receive their successors. The apparatus, used on a vast scale in Algeria, has cost many thousands of pounds sterling, the calico, the waxed and oiled cloth, the cords, stakes, and steel fastenings, and the plates of zinc being provided by the French government; while 850 workshops and offices have been established, and nearly 100,000 people have been employed in this grand operation. They are guarded by detachments of French soldiers. This plan has been attended with considerable success; the quantity of living insects already destroyed, in the spring months of this year, was estimated at more than half a million cubic yards. It is hoped by these means, combined with destroying the eggs, to put an end to the lamentable havoc of the grain crops in Algeria, which has caused great misery to an industrious agricultural nation.—*The Illustrated London News.*

ETHNOLOGY OF THE COAST INDIAN TRIBES OF ALASKA.

By Ensign A. P. NIBLACK, U.S.N.

THE strip of coast territory extending from Puget Sound to Cape Saint Elias and bordered on the east by the Cascade range of mountains, known in general as the Northwest Coast, is a continuous archipelago about 1,000 miles long and 150 miles broad. Through its narrow channels winds the steamer route to Sitka, and dotted along its shores are the picturesque winter villages of the Coast Indian tribes, an ethnic group corresponding to one of Bastian's geographical areas, materially differing not only from the hunting Indians of the interior, but in themselves presenting some of the most interesting problems in anthropology. The northern Indians of this region, comprising the Tlingit, Haida, and Tsimshian, may be called the wood-carving group; and the southern Indians, the Kwakiuti, Wakashan, and Coast Salish, the cedar bark group, such designations being based on the peculiarities of each in the use of wood and cedar bark, respectively, for industrial, ceremonial, and other purposes.

There have been three semi-official estimates of the Tlingit tribes of Alaska. The earliest is that in the archives of the Hudson Bay Company under Sir James Douglas (1839), made by Mr. John Work, a factor of the company. The total as given, including the Kaigani tribes of the Haidan stock, and adding on the Sitka and Hoonyah, which were omitted, is 8,975. In 1861 Lieutenant Wehrman, of the Russian navy, in the employ of the Russian American Company, compiled a census of Tlingit and Kaigani, giving the total population of free and slaves as 8,597. The third estimate appears in the Census Report of 1880, and places the Tlingit and Kaigani population at 7,225. That the enumeration is faulty goes without saying, when no real attempt was made to actually count them. What is needed is a census taken in the winter when the Indians are gathered in the villages, and it should include the enumeration of the different sub-totems and totems composing the great phratries of these tribes. This should be supplemented by an accurate plotting of the Indian hunting and fishing grounds which have been held in the different families and handed down for generations. A collection of the various myths and traditions, with all the local variations, and a study of the significance of the carved wooden columns in the villages is also needed to throw light upon their intricate totemic system. The semi-religious sects and the elaborate ceremonials and dances would in themselves constitute a special branch of study. In the U. S. National Museum is a magnificent collection of ethnological material from this region. What is needed is a systematic governmental supervision of the collection of anthropological data, and a comparison of results with those obtained in the southern portion of this region.—*Proc. U. S. National Museum.*

ON THE MENTAL FACULTIES OF ANTHROPOPITHECUS CALVUS.*

THE female chimpanzee which has now been in the society's menagerie for nearly six years has attracted general notice, not only on account of her peculiar zoological characters, but perhaps still more on account of her high intelligence. This is conspicuously displayed by the remarkable degree in which she is able to understand the meaning of spoken language—a degree which is fully equal to that presented by an infant a few months before emerging from infancy, and therefore higher than that which is presented by any other brute, so far, at least, as I have met with any evidence to show. Nevertheless, the only attempts that she makes by way of vocal response are three peculiar grunting noises—one indicative of assent or affirmation, another (very closely resembling the first) of dissent or negation, and the third (quite different from the other two) of thanks or recognition of favors. In disposition she is somewhat capricious, though on the whole good humored, fond of her keepers, and apparently never tired of a kind of bantering play which off and on they keep up with her continually. By vocalizing in a peculiar monotone (imitative of the beginning of her own "song"), they are usually able to excite her into the performance of a remarkable series of actions. First, she shoots out her lips into the well known tubular form (depicted in Darwin's "Expression of the Emotions," p. 141), while at the same time she sings a strange howling note interrupted at regular intervals; these, however, rapidly become shorter and shorter, while the vocalization becomes louder and louder, winding up to a climax of shrieks and yells, often accompanied with a drumming of the hind feet and a vigorous shaking of the network which constitutes her cage. The whole performance ends with a few grunts.

A year or two ago it occurred to me that I might try some psychological experiments on the intelligence of this animal. The circumstances in which she is placed, however, did not prove favorable for anything like systematic instruction. Being constantly exposed to the gaze of a number of people coming and going, and having her attention easily distracted by them, the ape was practically available for purposes of tuition only during the early hours of the morning, before the menagerie is open to the public; and, as a rule, I did not find it convenient to attend at that time. Therefore, the results which I am about to describe do not in my opinion represent what might fairly have been expected under more favorable conditions. If the chimpanzee could have been kept as a domestic pet for a few months (as I kept the cebus kindly lent me for the purposes of psychological observation by this society), there can be no doubt that many much more interesting results might have been obtained. Nevertheless, it appears to me that even those which thus far have been obtained are worthy of being placed on record; and although some of them have already been published a few months ago in my work on "Mental Evolution in Man," since that time some further progress has been made; and therefore in the present paper I will state together all the facts which have been hitherto observed.

Having enlisted the intelligent co-operation of the keepers, I requested them to ask the ape repeatedly for one straw, two straws, or three straws. These she was to pick up and hand out from among the litter in her cage. No constant order was to be observed in making these requests, but, whenever she handed a number not asked for, her offer was refused, while if she gave the proper number, her offer was accepted, and she received a piece of fruit as payment. In this way the ape was eventually taught to associate these three numbers with their names. Lastly, if two straws or three straws were demanded, she was taught to hold one straw or two straws in her mouth until she had picked up the remaining straw, and then to hand the two straws or the three straws together. This prevented any possible error arising from her interpretation of vocal tones—an error which might well have arisen if each straw had been asked for separately.

As soon as the animal understood what was required, and had learnt to associate these three numbers with their names, she never failed to give the number of straws asked for. Her education was then extended in a similar manner from three to four, and from four to five. Here, for reasons to be presently stated, I allowed her education to terminate. But more recently one of the keepers has endeavored to advance her instruction as far as ten. The result, however, is what might have been anticipated. Although she very rarely makes any mistake in handing out one, two, three, four, or five straws, according to the number asked for; and although she is usually accurate in handing out as many as six or seven; when the numbers eight, nine, or ten are named, the result becomes more and more uncertain, so as to be suggestive of guesswork. It is evident, however, that she understands the words seven, eight, nine, and ten to betoken numbers higher than those below them; for if she is asked for any of these numbers (*i. e.* above six), she always gives some number that is above six and not more than ten; but there is no such constant accuracy displayed in handing out the exact number named as is the case below six. On the whole, then, while there is no doubt that this animal can accurately compute any number of straws up to five, beyond five the accuracy of her computation becomes progressively diminished.

It is to be noticed that the ape exhibits some idea of multiplication; for she very frequently (especially when dealing with numbers above five) doubles over a long straw so as to make it present two ends, and thus to appear as two straws. Any of the comparatively rare errors which she now makes in dealing with numbers below six are almost invariably due to her thus endeavoring to duplicate her straws. In this connection it is to be remembered that owing to the method above described (whereby the ape is required to place each straw separately in her mouth until the sum asked for is completed), when any high number is demanded a considerable tax is imposed upon her patience; and, as her movements are deliberate while her store of patience is but small, it is evident to all observers that the doubling of the straws is intended to save trouble by getting the sum completed with greater rapidity than is possible when every straw is picked up separately. Of course we do not recognize these doubled straws as equivalent to two straws, and therefore the persistency with which she endeavors to palm them off as such is the more noteworthy as evidence of her idea of multiplication. Moreover I am disposed to think that the uncertainty which attends her dealing with the numbers six and seven is more largely due to her losing patience than to her losing count; although after seven I believe that her computation of the numbers themselves becomes vague, or merged in a merely general idea of many. It may also be stated that, while picking up the straws and placing them in her mouth, she looks only at the straws themselves and not at the person who asks for them: therefore she is certainly not actuated in her responses by interpreting facial expression, unconscious gesture, etc., as is no doubt the case with many dogs which on this account are sometimes accredited by their owners with powers of "thought reading." It is needless to add that, after asking for the number of straws required, we remain silent till the ape has handed them out.

It is not necessary—indeed it would be unreasonable—to suppose that in this process of "counting" the ape employs any system of notation. We know from our own experience that there is counting and counting, *i. e.*, distinguishing between low numbers by directly appreciating the difference between two quantities of sensuous perception and distinguishing between numbers of any amount by marking each perception with a separate sign. The extent to which the former kind of computation can be carried in the case of man has been made the subject of a careful research by Prof. Preyer, of Jena (*Sitz. Ber. d. Gesell. f. Med. u. Naturwiss.*, 1881). His experiments consisted in ascertaining the number of objects (such as dots on a piece of paper) which admit of being simultaneously estimated with accuracy, and it was found that the number admits of being largely increased by practice, until, in the case of some persons, it may rise to more than twenty. But of course in the case of a brute it is not to be expected that such a high degree of proficiency even in this non-notative kind of "counting" should be attainable. The utmost that could here be expected is that a brute should exhibit some such level of ability as is presented by a young child or by those savages whose powers of accurate computation do not appear to extend further than numbers which we write as units.* It was in view of such considerations that I did not attempt to carry the education of this ape beyond the number five; and the result which has attended subsequent endeavors to teach her numbers as high as ten is, as previously remarked, exactly what might have been anticipated. It may here be added that in the only records with which I am acquainted of animals exhibiting any powers of numerical computation, these powers have not extended beyond the number five. Thus, for instance, in his well known account of these powers as presented by rooks, Leroy says: "To deceive this suspicious bird, the plan was hit upon of sending two men into the watch house, one of whom passed out while the other remained to shoot the bird on returning to her nest; but the rook counted and kept her distance. Next day three went, and again she perceived that only two returned. In fine, it was found necessary to send five or six men to the watch house in order to throw out her calculations.†"

Again, Houzeau tells us that mules used in tramways at New Orleans have to make five journeys from one end of the route to the other before they are released, and that they make four of these journeys without showing any expectation of being released, but began to bray toward the end of the fifth.‡ Lastly, the keeper of the eared seals now in the menagerie has recently taught one of these animals to "count" as far as five. His method is to throw pieces of fish in regular succession, which the animal catches one by one. He throws them in series of fives, and before the commence-

* Paper read before the Zoological Society, on June 4, 1889, by Prof. George J. Romanes, F.R.S.

* See, for instance, Galton, "Tropical South Africa," p. 213.

† "Letters," etc.

‡ "Fac. Ment. des Anim.," tom. ii., p. 277.

ment of any series, he tells the seal to miss the first, the second, the third, the fourth, or the fifth, as the on-lookers may dictate: the seal thereupon makes no attempt to catch the member of the series thus verbally indicated. It is only a day or two ago, however, that I witnessed this performance, and as yet I am not satisfied that the seal really "counts," because it appears to me probable that the keeper may unintentionally throw with some slight difference in his manner of throwing the piece of fish which he expects the seal to miss, and that it is really this slight difference in the manner of throwing which the seal perceives and acts upon. Therefore, I intend to get an arrangement fitted up whereby the pieces of fish shall be thrown mechanically. But, whatever the result of this experiment may be, I think there can now no longer be any question that it lies within the capacity of animal intelligence to "count" correctly (in the sense already explained) as far as five, and even to show a well marked appreciation, although progressively a more and more uncertain one, of numbers lying between five and ten.

The only other direction in which I have thus far subjected the chimpanzee to psychological experiment has been in that of attempting to teach her the names of colors. It appeared to me that if I could once succeed in getting her thoroughly well to know the the names of black, white, red, green, and blue, a possible basis might be laid for many further experiments wherein these five colors could be used as signs of artificially associated ideas. The result, however, of attempting to teach her the names of colors has been so uniformly negative, that I am disposed to think the animal must be color blind. It is perhaps desirable to state the facts which have led me to entertain this as their most probable interpretation.

The method adopted in these experiments was to obtain from the importers of Oriental matting a number of brightly and uniformly colored pieces of straw—each piece being either white, black, red, green, or blue.

Taking the straws two by two of different colors, on each occasion the ape was invited to chose the straw of the color named from one whose color was not named, and of course on choosing correctly she was rewarded with a piece of fruit. In this way she quickly learnt to distinguish between the white straws and the straws of any other color; but she never could be taught to go further. Now the distinction between the white straws and the straws of any other color is a distinction which could have been drawn by an eye that is color blind; and from the fact that the ape is always able to perceive this distinction (she will search long and patiently for a straw of any color when told that it occurs somewhere in the general litter of white straws constituting her bed, and eventually picks it out), while she cannot be taught to distinguish any of the others, I conclude that her failure in this respect is not due to any want of intelligence, but to some deficiency in her powers of color perception.

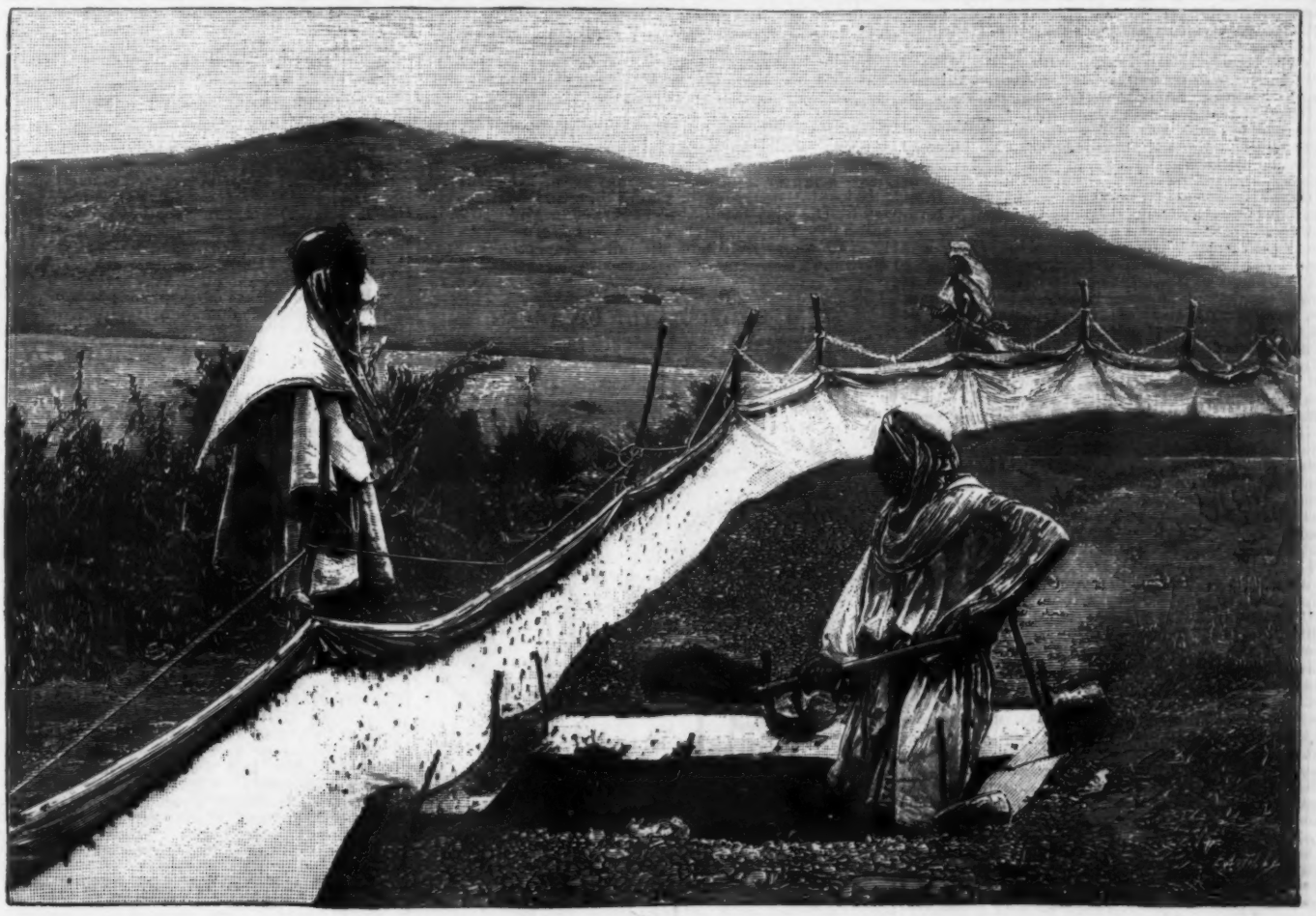
REMARKABLE DISCOVERIES IN EGYPT.

THE two large July gatherings held in London, England, by the Victoria Institute are considered to have been of much importance. The President, Sir G. G. Stokes, Bart., President of the Royal Society, took the chair at both, and on each occasion the members crowded the large hall engaged to the doors. At the first meeting, Professor Sayce's account of his examination of the library brought by Amenophis III. from Assyria to Egypt, 34 centuries ago, was given. The Lord Chancellor delivered an eloquent speech on the occasion, and M. Naville, the discoverer of Succoth-Pithon, Bubastis, and other places of great historical importance in Egypt, characterized the discovery described by Professor Sayce as one of the most important, and perhaps really the most important, of this century; and the Victoria Institute's members were not slow in recognizing the value of their fellow-member's work. At the second meeting, the members assembled to welcome M. Naville on his arrival in England after his discovery of the site of Bubastis and his exploration thereof. The business of this meeting was commenced by the election, as members, of several who had applied to join the Institute as supporters, including His Excellency Count Bernstorff, and several Australian and American associates, after which M. Naville himself described his own discoveries at Bubastis, for the first time in England, his last visit to England having been previous to those discoveries. The Society of Arts having most kindly placed their apparatus at the disposal of the Victoria Institute, he showed, by lime light, the photographs he had made on the spot.

M. Naville commenced by quoting the prophecy of Ezekiel against Egypt, because it contained the names of the leading buried cities, the recovery of the records of which he is so desirous to obtain; and here we may be permitted to digress for a moment to call attention to the fact that the authoress of the last published work in regard to the East declares that this prophecy had not been fulfilled according to the prophet's words. Strange that the greatest and most successful Egyptian explorer of modern times should go to this very prophecy for light to enable him to find that which others had failed to discover! Taking the last city named, he described how he found Pibseseth-Bubastis, how each day's excavating work brought him new relics, new inscriptions; how he found Rameses II., in the 19th dynasty, had, as usual, blotted out the names of previous Pharaohs, and put his own on everything, even on the statue of Pharaoh of the 4th dynasty; and how, by careful comparison, aided by the fact that Rameses II. had not been quite thorough in his appropriations, he had discovered which Pharaoh of the 4th dynasty the statue represented. He came to the conclusion that Bubastis was founded at least as early as in the reign of Cheops, between whom and Pepi, of whose influence there were traces, 500 years intervened; 800 years after there was a transformation of the city in the 12th dynasty; in the 14th dynasty there was the invasion of the Hyksos or shepherds, who, from the statues of great beauty found, and from other evidences, must have been a highly cultivated people, who, he considered, must have come from Mesopotamia. Dr. Virchow considered that their monuments represented Turanians, and Professor Flower considered them to represent people of a Turanian or Mongoloid type, but that did not mean that the population itself was Turanian. Their worship and language was of a Semitic type, but the statues of their kings showed that they were not Semites. M. Naville added: "It was then what it is still now; and I believe that the conquest of Egypt by the Hyksos is not unlike what would happen at the present day if the population of Mesopotamia overran the valley of the Nile; you would have masses, in great majority of Semitic race, speaking a Semitic language, having a Semitic religion, and being under the command of Turks, who are not Semites but Turanians."

M. Naville, having referred to the head of a Hyksos king which he had sent to the British Museum, added that he had found two statues of Apepi, the Pharaoh of Joseph, and inscriptions in regard to the Pharaoh of the Exodus, and many others of high interest. But it would be impossible to refer to the mine of interesting matter in this paper, and we can only congratulate the members of the Victoria Institute on possessing it; it is certainly worth the whole year's subscription to possess this one paper. M. Naville, in concluding, said: "I cannot dwell at great length here on the events of the Exodus, yet I should like to mention that the successive discoveries made in the Delta have had the result of making the sacred narrative more comprehensible in many points, and in one especially in showing that the distances were much shorter than was generally thought. I consider, for instance, it important to have established that Bubastis was a very large city, and a favorite resort of the king and his family. It is quite possible that, at the time when the events preceding the Exodus took place, the king was at Bubastis, not at Tanis, as we generally believed."

Sir George Stokes, Bart., having conveyed the thanks of the members to M. Naville, a short discussion took place, during which Captain Francis Petrie, the honorary secretary, pointed out that what Professor Sayce's paper had done as regards Assyrian and Babylonian history, M. Naville's had done as regards Egyptian history. They were papers advancing the practical work of the Institute in investigating philosophical and scientific questions, especially questions used by those who attacked the Bible in the name of science; and both would appear in the *Journal*, which would be presented at the Institute's rooms, 1A Adelphi Terrace, to all members and associates who were now on the list, or who might apply to join after the 10th of July. The president, members, and associates then adjourned to the museum, where refreshments were served.



A CRICKET TRENCH IN ALGERIA.

[NATURE.]

THE PLANET URANUS.

THAT anomalous section of the solar system, Uranus and its satellites, offers yet a wide field of investigation to astronomical specialists of all kinds. Its figure, its rotation, satellites, and physical constitution altogether are moot points, which should be more or less settled with the increased optical power now at our disposal.

The circumstances attendant upon the discovery of Uranus in 1781 (*Phil. Trans.*, 1781, p. 492) are matters of common knowledge. The planetary nature of the supposed comet seems to have been first suspected by Maskelyne, and it was this suggestion that induced Lexell to calculate for it a circular orbit in 1781 (Grant's "History of Physical Astronomy," p. 274). The elliptic elements of the planet were first calculated by Laplace in 1782 (*Mém. Acad. des Sciences*, Paris, January, 1788).

The first measures of the Uranian diameter were singularly incongruous. Herschel found it in March, 1781, to be 2″·53; while in the following month he measured it as 4″·32 and 5″·2 (*Phil. Trans.*, 1781, p. 494). A like discordance occurred in the results obtained by other astronomers. Maskelyne fixed the magnitude of the apparent diameter as 3″, while Mayer, of Manheim, estimated it to be as high as 10″ (Grant's "History of Astronomy," p. 275).

The difference between these measures of the diameter of Uranus would seem to be a consequence of the fact that it is always extremely difficult to get the

planet clearly defined in the field of the telescope. Herschel himself noted (*Phil. Trans.*, 1798, p. 68), "The Georgian planet is not so well defined as, from the extraordinary distinctness of my present 7-foot telescope, it ought to be. There is a suspicion of some apparatus about the planet."

Herschel several times had the impression that Uranus was surrounded with a ring. One of his observations is contained in the following (*Philosophical Transactions*, 1798, p. 68): "My telescope is extremely distinct, and when I adjust it upon a very minute double star, which is not far from the planet, I see a very faint ray, like a ring crossing the planet, over the center. This appearance is of an equal length on both sides, so that I strongly suspect it to be a ring. . . . I have turned the speculum one quadrant round, but the appearance of the very faint ray continues where it was before, so that the defect is not in the speculum nor is it in the eye-piece." Later observations, however, led Herschel to conclude that "Uranus has no ring in the least resembling that, or rather those, of Saturn."

Following upon the observations as to the existence of a ring round Uranus, are found others relating to its polar compression. The flattening at the poles was first observed by Herschel in February, 1794 (*Phil. Trans.*, 1798, p. 69), and announced in the following words: "The planet seems to be a little lengthened out, in the direction of the longer axis of the satellite's orbit;" and again in April of the same year: "The disk of the planet seems to be a little elliptical." Mädler measured the ellipticity in 1843, and found it 1/9·92 (Grant's "History of Astronomy," p. 278). Schiaparelli, in 1883, using two different methods, obtained the results 1/10·98 and 1/10·94 (*Astr. Nach.*, No. 2526). A few measures made by Young in the same year gave an ellipticity 1/14 ("General Astronomy," Young, p. 367). The fact that the ellipticity was in the same plane as the major axis of the satellite's orbit led Herschel to conclude from analogy with Jupiter and Saturn that "the Georgian planet also has a rotation upon its axis of a considerable degree of velocity" (*Phil. Trans.*, 1798, p. 71). Other observers of the bulging out of the Uranian equator—Schiaparelli, Young, Safarik—agree with Herschel in saying that the plane is coincident with that of the satellite's motion, but the following observations of markings on the surface of Uranus lead to an entirely different conclusion.

Buffham noticed some bright markings on Uranus in 1870–72 (*Monthly Notices*, vol. xxxiii., p. 164), and, from observations of their motion, deduced the time of rotation as twelve hours, but the plane of rotation was *not* coincident with that of the satellite's orbit. This was borne out by the observation of dusky bands by Young in 1883 ("Princetown Observations," 1883); of apparent equatorial belts by the brothers Henry, in 1884 (*Comptes Rendus*, t. xcviii., p. 1419); and observations in 1884, at Nice, of a bright spot by Lockyer, Perrotin, and Thollon (*Comptes Rendus*, t. xcviii., pp. 717, 967). The plane of rotation, according to these observers, is from 15° to 40° from the trend of the satellite's. Thus the difference between the two sets of observations amounts to nearly half a right angle. Does the error lie in the observation of the belts or in the measurements of the planet's ellipticity and the satellite's orbit? This is an enigma which yet remains to be solved, and another character of Uranus requiring investigation.

Herschel made the first determination of the mass of Uranus in 1788 (*Philosophical Transactions*, 1788, p. 369), and found it to be 17·740612 as compared with the earth, or about 1/18,000 that of the sun. Bouvard found a value of 1/17,918; Lamont, in 1837, 1/24,605. Lassell's observations of the motion of the satellites gave a value 1/20,897, while Struve's observations gave a value 1/26,800. The mass, 1/22,600, found by Newcomb ("Washington Observations," 1873), is probably the most correct, and he estimates that the probable error in the denominator is not more than 100. This mass, revolving round the sun at a mean distance of about 1,800 millions of miles, must exert considerable influence upon bodies near it, influence which may often predominate over that of the sun.

But it is the question of Uranian satellites that is so enigmatical. Herschel discovered two on January 11, 1787 (*Phil. Trans.*, 1787, p. 125 *et seq.*), and in 1798 announced the discovery of four more. Regarding the real existence of these four, Herschel remarks (*Phil. Trans.*, 1798, p. 66): "It remains now only to be mentioned that, in such delicate observations as these of the additional satellites, there may possibly arise some doubts with those who are very scrupulous; but as I have been much in the habit of seeing very small and dim objects, *I have not been detained from publishing these observations sooner, on account of the least uncertainty about the existence of these satellites*, but merely because I was in hopes of being able soon to give a better account of them, with regard to their periodical revolutions."

Sir John Herschel observed the two brightest satellites between 1828 and 1832 (Mem. Ast. Soc., vol. viii., p. 1); but "of other satellites," he says, than these, "I have no evidence," although the telescope he was using was precisely similar to that used by his father. A systematic search was made by Lassell for the lost satellites, and a definite announcement of the discovery of two satellites between Uranus and the two brightest was made in 1851 (*Monthly Notices R.A.S.*, xi., 248). He declares, however, that it would have been impossible for Sir William Herschel to have seen these two faint bodies; and although Prof. Holden has attempted to identify the two with two of Herschel's quartet, the balance of evidence is certainly to the contrary, and we are bound to conclude that no one has ever seen the four but Herschel himself.

Herschel announced in 1798 (*Phil. Trans.*, 1798, p. 48), the retrograde movements of the Uranian satellites in the terse paragraph, "I take this opportunity of announcing that the movement of the Georgian satellites is retrograde." The fact that their orbits were inclined about 80° to the ecliptic plane was discovered in 1788.

Herschel also particularly noticed that the light of the two brightest satellites was subject to considerable fluctuations, and in 1815 (*Phil. Trans.*, 1815, p. 356) he suggests for a cause that given by Newton in the "Principia" to account for the periodical variability of certain stars. His conclusion was: "The variable brightness of the satellites may be owing to a rotation upon their axes, whereby they alternately present different parts of their surface to our view. These variations may also arise from their having atmospheres that occasionally hide or expose the dark surface of their bodies, as is the case with the sun, Jupiter and Saturn."

The two inner satellites, Ariel and Umbriel, discovered by Lassell, seem also to fluctuate in brightness, and Newcomb observed in 1875 ("Washington Observations," 1875, p. 43): "I strongly suspect that Ariel, at least, belongs to that class of satellites of which the brilliancy is variable and dependent on its position in its orbit. The evidence of variability of some kind seems indisputable, as I have repeatedly failed to see it when the circumstances, distance from the planet included, were in every respect favorable, and when Umbriel, though less favorably situated, was visible. On the other hand, there were two occasions, January 28, 1874, and March 25, 1875, when it was surprisingly conspicuous. Unfortunately no systematic record was made of the times when, being near greatest elongation, it was looked for and not seen; but on at least one such occasion its position angle was 180°. An inspection of the observations shows that out of the eight observations only two were made near the southern elongation; while in the two cases where its brightness was most remarkable, the position angles were respectively 348° and 351°."

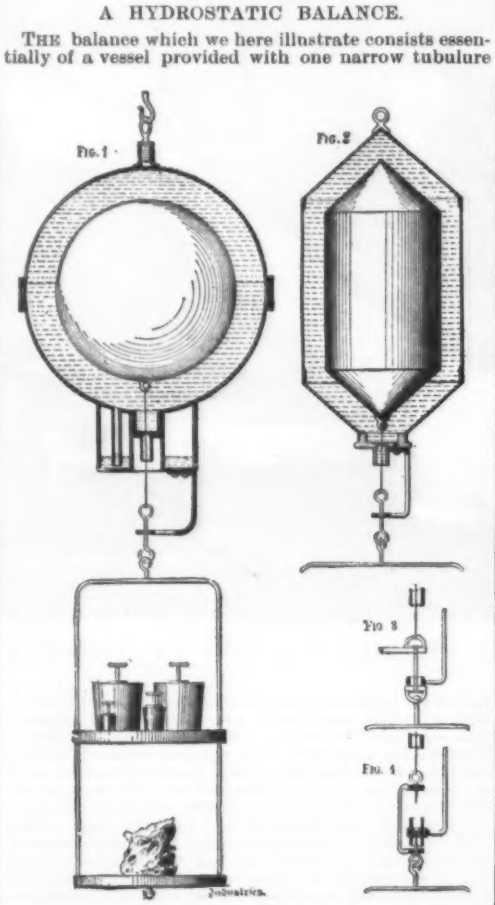
The time of revolution of Ariel is 2·520378 days at a mean distance of 120,000 miles; its diameter is about 500 miles.

Herschel also observed that these satellites became invisible some distance from the planet's disk (*Phil. Trans.*, 1798, p. 75); thus, on February 22, 1791, the first satellite was lost when 22° from the planet. This distance was not, however, constant, for on May 2, 1791, the same satellite disappeared at an apparent distance 19°·8. A table is given showing at what distance from the planet the first and second satellites respectively became invisible during a period of seven years. A fact exhibited by this table is that the distance at which the satellites disappeared regularly diminished from 1791 to 1797, until in the latter year the first satellite was traced to 4°·8 from the planet's disk. The reason assigned to account for this phenomenon by Herschel was that the light of the satellites was "put out" by the stronger light of their primary, and regarding this he remarks (*Phil. Trans.*, 1798, p. 78): "We may avail ourselves of the observations that relate to the distances at which the satellites vanish, to determine their relative brightness. The second satellite generally appears brighter than the first; but as the former is usually lost farther from the planet than the latter, we may admit the first satellite to be rather brighter than the second." The diameters of the first and second satellites are about 1,000 and 800 miles respectively, hence Herschel's comparative measures were correct.

R. A. GREGORY.

A HYDROSTATIC BALANCE.

THE balance which we here illustrate consists essentially of a vessel provided with one narrow tubulure



opening, and suspended so that the tubulure is downward, and when filled with liquid none will escape. Within this is a second vessel, closed and made of such light material that it readily floats in water. To the lower end of the inner vessel is suspended a fine wire which passes through the tubulure of the outer vessel, which is attached to a nozzle. When the nozzle is unscrewed, and the vessel is turned up, the space surrounding the float can be readily filled with water. The diameter of the tubulure is 3 mm., so that the water will not flow out even if the apparatus is shaken or rolled about on a table.

When the balance is hung up, the inner vessel or float will tend to ascend within the liquid; and if, as shown in Fig. 1, we hang a pan on the wire, and place weights on the pan, we find that we can add weights up to a certain amount, when the pan will begin to descend with the float within the vessel. The weight required to cause the pan to just begin to descend may be assumed to be constant and equal to W, which is equal to the weight of a mass of water having a volume equal to that of the float minus the weight of the float, of the wire, and of the pan attached to the wire. Hence we can ascertain the weight of any mass which is not heavier than W, for the arrangement is equivalent to using a balance one arm of which is loaded with a constant weight, W.

In order to weigh any substance, it is placed in the pan, and weights are added until the pan begins to descend, when we know that a total weight, W, is in the pan. If w is the weight added, and x the weight of the substance, then $x = W - w$. Practically, W is a quantity which is not constant, but varies with the temperature of the float and of the water, so that when accurate results are required, we cannot assume any constant for the balance, but must make a new determination of W for every determination of w. This, however, can be very easily done by the well known method of substitution.

The apparatus is identical in principle with Nicholson's hydrometer used as a weighing machine, the hydrometer being inverted while retaining the liquid. By inverting the hydrometer we get this important difference, that while formerly the stem supporting the pan was in compression it is now in tension, and hence may be made extremely fine, as it does not require to be stiff, and the effect of the adhesion of the liquid is materially reduced. The effect of the friction of the wire against the collar of the tubulure is found in practice to be so small as to be inappreciable. In Fig. 1 a collar of burnished agate was substituted for the brass collar of Fig. 2, but with hardly any measurable difference in the result.

In the balance shown in Fig. 1 the float is a sphere of light blown glass weighing about 12 grammes and about 6·3 cm. in diameter. The outer vessel is of brass, parting in a screw joint into hemispheres. The double pan, suspended by a light brass wire 0·9 mm. in diameter, is of brass, and with the suspending gear weighs about 11 grammes. The balance is protected from draughts and sudden changes of temperature by a glass case, from the roof of which it hangs freely. The weights are introduced at a half door in the lower part of the case, which does not require leveling screws. The balance will estimate the weight of 100 grammes to an accuracy of 100,000.

In Figs. 1 and 2 there is shown a double-eyed link to which the suspension wire is attached, and which runs through an eye which prevents the float reaching either to the top or bottom of the containing sphere or vessel, and also in case the wire should break arrests the descent of the pan. Figs. 3 and 4 show two bearings for regulating the amount of motion; in Fig. 3 there is contact at two points, when the link is at either limit; in Fig. 4 there is contact at one point only.

In the balance shown in Fig. 2, there is no provision made for the effects of variations in temperature, and any considerable change in temperature will either draw air into the containing vessel or expel some of the contents. The effects of slight changes of temperature are not important. Thus, with concentric spheres of brass, the inner having a diameter of 7 cm. and displacing 179 grammes, and the outer having a diameter of 9 cm., the intervening space being filled with water, a change of temperature of 1° C. will displace 14 cubic mm. of water, or about half a drop. The entry of a little air will do no harm; it merely rises to the top of the vessel, and in no way interferes with the truth of the observations, while a little expelled water is easily dried off. If it is desired to have the apparatus compensated, an arrangement such as that shown in Fig. 1 will answer the purpose. Here an expansion reservoir is provided, which surrounds the tubulure and communicates with the interior of the sphere by a narrow tube reaching nearly to the bottom of the reservoir. Hence, when the temperature rises, the reservoir receives the expelled water; when the temperature falls, it parts with some of its contents, and no water is lost.

The apparatus may be used for determining the specific gravities of solids by using a small claw for supporting the substance under water. This is suspended by a fine wire from a hook beneath the pan. The substance is first weighed in the pan, the claw being attached and immersed in a vessel of water placed underneath. On transferring the substance to the claw an increased weight will be required to produce equilibrium, which increase is evidently the weight of displaced water. This balance is a great improvement on the ordinary ones, combining as it does great delicacy with cheapness and compactness. It was invented by Mr. J. Joly, B.E., Trinity College, Dublin.—*Industries.*

PYROMETERS.

THE methods employed for the determination of high temperatures—the temperature of furnace fires, flue gases, molten metals, etc.—may be divided into four classes: (1) Those which depend for their indications upon a change of dimensions of a body employed in the test; (2) those based on the amount of heat imparted to a body of water or air by the heated body; (3) those depending upon the melting points of metals and metallic alloys; and (4) those dependent upon the measurement of the electrical resistance of metals.

The first method was employed by Wedgewood, who constructed, in 1782, the first instrument by which high temperatures could be measured with any approach to accuracy. His instrument is based on the property possessed by clay to contract when exposed to high heat, an effect which is believed to be due partly to the loss of its water, and partly to the process of vitrification which sets in subsequently. It has been found, however, that the assumption by Wedgewood, that the contraction of clay is proportional to the degree of heat to which it is subjected, is incorrect; and that a long continued heat of moderate intensity will cause the same amount of contraction as a more intense heat for a shorter time; and, further, that different clays differ considerably in the degree of contraction which they suffer when subjected to the same temperature. For these reasons the method of Wedgewood has been abandoned in scientific measurements, as unreliable, although it gives results in many cases approximating sufficiently to the truth for all practical purposes.

In the pyrometer of Daniell the temperature is measured by the expansion of a metal bar inclosed in a black lead earthenware case. The metal of the bar is either platinum or soft iron. The expansion of the

bar causes the motion of an index of porcelain on a suitably graduated scale. The second method, which is that most generally in use in metallurgical operations, consists in placing a mass of platinum of known weight in the medium whose temperature is to be ascertained, and when it has acquired the same temperature, plunging it into a body of water of known weight and temperature. From the indicated rise of temperature of the water, the known relation between the weights of the platinum and the water, and their relative specific heats, the data are given for the estimation of the temperature to which the platinum was originally heated.

A method similar in principle to this is in common use to determine the heat of furnace and flue gases. It is based on the plan of mingling with the heated furnace or flue gases a definite volume of air of known temperature, the assumption being that if an equal volume of air is mingled with the hot gases, their temperature will be reduced one-half; if twice the volume, two-thirds; if three times, three-fourths; if nine times the volume, nine-tenths, etc. By thus mingling a large volume of cold air with the hot gases, the temperature of the mixture will be reduced sufficiently to permit it to be measured by means of thermometers or by the expansion of a metal bar.

The third method, based on the melting points of certain metals and alloys, is practiced by simply suspending in the heated medium a piece of metal the melting point of which is known, or, if necessary, several pieces of different (but known) melting points. According to the observations of the pieces which are melted, and those which continue to remain solid, the temperature of the medium may be ascertained within a very narrow limit of error.

The fourth method is a much more refined and scientific one, devised by Siemens, and is based on the principle that the electrical resistance of metals stands in a certain relation to the temperature, an increase of the latter causing a corresponding increase of resistance. The resistance of a given piece of metal of known material and dimensions being ascertained by measurement with the aid of suitable apparatus, its resistance for any given temperature can be calculated, and *vice versa*. This treatment will be found described in the special treatises on electricity.

THE RAILWAYS OF INDIA.

INDIA has now 16,000 miles of railroad, says Frank G. Carpenter, the newspaper correspondent, in a recent letter from Bombay to the *Salt Lake Herald*. It is as far from Calcutta to Bombay as it is from New York to Denver, and several trunk lines cross Hindostan from one city to the other. There are branches from these which go up the Himalaya mountains almost to the borders of Thibet, and others which shoot off to the Khyber Pass at the entrance to Afghanistan and not a great distance from the new Russian railway, which has been pushed on past Samarcand. South India has many long lines of railroads, and the whole of Hindostan, which is half the size of the United States, has a railroad net covering it. The construction of these railroads has included engineering works fully as grand as the railroad making of the United States, and the keeping of them in order is more difficult. One of the great plagues of India railroad makers is the white ant. These insects eat every dead thing in wood form above ground. If a pile of wooden ties is left over night, an attack of ants will have carried it away by morning, and there is no possible storage of wooden ties. Such ties as are in the roads are saved from destruction by the vibration caused by the running trains, which scares the ants away. It is the same with telegraph poles and fences, and the result is that the ties of most of the railroads are made of iron.

I have traveled about three thousand miles over all kinds of railways in India. The telegraph poles on many of the lines are hollow tubes of galvanized iron, about as big around as the average man's calf, so made that they fit into one another and form a pole about 10 ft. high. To these poles the lines are strung, and many of the roads use such poles throughout their entire length. On the other lines the telegraph poles are T iron rails, the same as those on which the car travels. Two of these rails are fastened together by bars about a foot wide and then this iron work is set deep in the ground and the wire strung upon it. About some of the stations the fences are made of such iron rails, and through hundreds of miles along one of the rajah's railroads in western India I found fences of barbed wire with sandstone posts. These posts were a foot wide and four inches thick, and they stood about three feet above the ground. The wires ran through holes in them, and the railroad men tell me that they are much cheaper than wood.

I am surprised at the magnificence of the railroads in India. Here at Bombay there is a finer railroad station than any we have in the United States. It cost about one million dollars, and architecturally it is the peer of any building at Washington. At Calcutta there are fine depots, and even at the smallest of the towns you will find well made stone buildings surrounded by beautiful gardens in which bloom all kinds of tropical flowers. Nothing about these stations is made of wood. The platforms are of stone filled in with cement, and the cars run into the stations on a plane about two feet below the floor and so that the floor of the cars is just even with that of the depot. Each station has its first, second and third class waiting room, and everything in India goes by classes. The cars are first, second, third and fourth class, and they are all on the English plan. They are about two-thirds the length of our cars and a trifle wider. They are not so heavy as the American passenger coach and they look more like wide, long boxes than anything else.

Each of these cars is divided into compartments. There are only two compartments to the car, and the chief difference in these two classes is in the number allowed in the compartment. If you will imagine a little room about 10 ft. long by 5 ft. wide, with a roof 7 ft. high, in the center of which there is a glass globe for a light, you may have some idea of the Indian first class car. You must, however, put two long, leather covered, cushioned benches along each side of this room and at the end of these have doors with glass windows in them, opening inward. Over the cushioned backs of the benches there are windows which are let up and down like those of the American street car and which are of the same size. The car has none of the finish of the American Pullman, and though you are expected to sleep within it there are no signs of bedding or curtains. At the back of it there is a lavatory without towels, soap or brushes, and there is barely room enough for you to turn around in it when you are washing. The second class cars are much the same, and there may be one second class car and one first on the same coach.

Every man carries his own bedding with him in India, and these Indian cars give you nothing else but a lounge on which to spread a cotton comforter, a shawl or a rug. You carry your own pillows, and the bedding of half a dozen passengers would fill a car. Each traveler of the first and second classes brings the most of his baggage into the train with him, and there is often as much as the contents of an American baggage car in one of these compartments. No one undresses, but all lie down with their clothes on, pull their shawls over them and sleep the best they can. Women traveling alone universally go into compartments reserved for women, and men traveling with their wives have often trouble in keeping together. This luggage being brought into the cars and the trouble about getting and holding seats lead us to the necessity, which exists in India, of traveling with a servant. All English and American travelers carry one or more servants along with them, and in figuring up your railroad fares you must add to the fare of the class by which you travel a third class fare for your native servant.

Only rich natives travel second class in India. The bulk of the first and second class travel is made up of English and Americans. The natives, as a rule, go by the intermediate or third class, and the third class fares here are the cheapest in the world. They are by ordinary trains less than one-half cent per mile and by mail trains only nine-sixteenths of a cent. Still the third class passengers at this low rate pay more to the roads than either the first or second class, and railroad managers tell me they believe it will pay to reduce this rate much lower than it now is. Here in India there is a vast difference between the prices of the various classes. First class is, on the great Indian peninsula railroad, which is a fair type of the whole, two and one-half cents per mile. Second class is just one-half this rate, and intermediate one-half of second class. Third class is one-half the intermediate, and the third class pays. The third class cars carry thirty-two passengers. They are divided into compartments with benches uncushioned, running so across the car that the passengers face each other, and the passengers are packed in as close as sardines. They are always full, and the East Indians travel as much as do the citizens of the United States. I have yet to find a train in which the third class cars were not packed, and many of those upon which I rode had three times as many third class cars as first and second class. Each native carries with him a bundle containing his brass pot, out of which he drinks, and often the pans with which he cooks his food.

The Hindoo women travel as lightly as the men, but the two sexes are never put into the same cars. There are closed cars on all of the trains for high caste Hindoo women, and these have windows of blue glass in the first and second classes, which permit the women to look out, but which prevent the men from looking in. In some of the cars the windows of the women's compartments are so fixed with shutters that there can be no looking out, and in the train which carried me to Darjeeling there was one car covered entirely with canvas as thick as that of a circus tent. This contained Hindoo women, who, as they rode up the Himalaya mountains through the finest scenery in the world, were thus shut in the stuffy darkness of this tent-like car and saw no more of the grandeur of nature about them than they would have seen had they been tied up in so many leather bags and sent along as mail.

One of the greatest roads in India is the East India Railway. This railway has a curious method of investing a percentage of the wages which it pays its hands, which is found to work both to the advantage of the railway and the employes. Wages are very low in India, but through this method many of the employes have become rich. All of the hands who receive over 30 rupees or $10 a month have to pay 2 per cent. of their earnings into a certain fund. They can pay as much more than 2 per cent. as they please. The road receives the money, pays interest on it, and upon their leaving the service honorably gives them back double the amount they have paid in, with interest. This seems incredible, but I am assured it is so. An English clergyman told me that he knew a railroad employe who went in at $10 a month and who will soon take out $5,000. This method was entered into at the time the railroad was built. The managers were hard up for capital, and they wished to bind their hands to them. The company is now prosperous, and it keeps up the same system. I find that section men work here for from three to five cents a day, and that the roads can get all the men they want at these prices. Engineers work on time and distance, and they are about the highest paid of the railroad employes. They get about $70 a month while running regularly, but they can increase this by extra running to $85 and $100 a month. The Indian railways have no conductors in our sense of the word. The tickets are collected and examined by men at the various stations, and the guard who manages the train in other respects has nothing to do with the tickets. Such guards get about $25 a month, and on the smaller railroads they receive from $7 to $20 a month. The most of the guards are natives or half breeds, while a majority of the engineers are English. I don't think the English engineers are as well posted as our American ones. I asked one of them the weight of his engine. He stammered and replied that he did not know. The engines here are lighter than ours, and the whole equipment of the railroad is upon a smaller scale. Most of the freight cars are made of iron, and you could crowd three of them into one American caboose. They carry on an average about six tons, have no trucks and only four wheels. None of these freight cars are managed by brakes from the top, and you see no brakemen trotting along on the tops of the trains. Freight in India is measured by the mound, or 80 lb.

Nearly all the railroads in India are under the government, and many of the roads were built by the government guaranteeing 5 per cent. to the stockholders on the condition that the profits above 5 per cent. shall be equally divided between the government and the stockholders. Over others of the roads the government has a sort of a control, and the result is that the tenure of place on the railroad is much the same as that of the civil service of England. Men expect to stay a lifetime when they enter the railroad service, and there is no danger of their discharge during good behavior. There are no strikes in India, and a position on the railroad is considered very desirable by the natives. The laws are, on account of the government owning the roads, almost altogether in favor of the road, and our farmers would rise in indignation at some of them. If an American has a cow killed on the track of a road running through his farm, the railroad company pays well for it. In India the owner of cattle found trespassing on the railroad is liable to a penalty of $3.50 for each animal. Any man who drives an animal across an Indian railway, except at certain appointed times and places, is liable to a fine of $17, and any man who enters a car reserved for females can be fined $35. The man who tries to get on a train here after it is started will be fined $7, and any one who attempts to defraud the railroad company in any manner is liable to a fine of $16. The postal cars are in the middle of the train, and the postal clerks are natives. It takes about twice as many clerks to manage the mail as with us, but the service is much cheaper. The head clerk gets about 70 rupees a month, or less than $30, and the others receive from $10 to $20 a month. Letters are sorted on the train, and extra postage is charged for the posting of letters at the trains just before the car starts.

THE ENGLISH ENGINE ON THE PENNSYLVANIA RAILWAY.

IT is very probable that within a short time American locomotive builders will take a leaf from the Englishmen that will make an important change in the style of locomotives in use in this country. Some time ago the Pennsylvania Railroad ordered from a firm of English locomotive builders an engine of the type that has for several years been commonly in use upon English railroads and to some extent upon Continental lines. The locomotive was built and sent over here in sections. English machinists came along to set it up in the company's shops at Altoona, and an English engineer and fireman were on hand to run it when it was ready. It was tried for a while on the Pittsburg division, west of Altoona, and then, when it was certain that it was in perfect running order, it was brought east, its English driver and stoker were sent home, and it was turned over to the motive power department of the New York division to be put to regular work to see what could be done with it.

In appearance it is the typical English engine, heavy looking and dull, with its working parts well out of sight. It is just as it would appear on an English road, except that a cow catcher has been added to its front and a bell set up on its boiler. It has a single front wheel on each side, instead of the two customary on American locomotives, and they are hung on what is known as a radial axle box, which is merely another contrivance for making the truck swing freely around a curve, which is accomplished in the American locomotives by the use of a pivotal bearing for the truck.

At a casual glance the drive wheels do not look unlike those of an American engine, but the really important thing about the locomotive is in them and the way they are operated. Each set of wheels is independent of the other, instead of the two pairs being linked together by bars. The rear pair of wheels is connected with a cylinder similar to that of American engines, but placed lower down and between the front truck and the front driver. There are two cylinders, one on each side. Between these two and underneath the boiler is a third cylinder, the rod from which connects with a crank in the axle of the front drivers. The steam from the boiler goes first to the pair of cylinders connected with the rear drivers. When it has done its work in them, it still retains considerable "life" or expansive power, and instead of passing off into the open air, as in the ordinary locomotive, it is turned into the third cylinder, where the rest of its force is exerted upon the front drivers.

On account of this double use of the steam the locomotive is called a compound one, although this is not strictly accurate, as a compound engine has a condenser attached to turn the exhaust steam into water, so that it may be used over and over again. The English locomotive is really a double expansion one, but not compound. The double expansion system has long been used on marine engines, and has been extended until triple expansion engines are now generally used on fast boats, but the necessity for economizing space and weight has until recently prevented the compounding of railway engines.

These are some other figures that will give an idea of the style and build of the Pennsylvania, which is the name of the English locomotive: Diameter of drivers, 75 inches; diameter of cylinders, high pressure (outside ones), 14 inches, and low pressure (inside one), 30 inches; length of stroke, 24 inches; height of stack above top of rail, 12 feet 10 inches; width over all, 8 feet 2½ inches; length over all, engine and tender, 52 feet 7 inches; weight in working order, 99,350 pounds; weight of tender, loaded, 57,850; steam pressure, 175 pounds.

The locomotive has now been running nearly a week on one of the hardest runs in this part of the country. It takes the Long Branch special out of Jersey City at 3:52 o'clock every afternoon and brings it back next morning. It is a heavier train than the average fast passenger train, and its time for the run of forty-eight miles is 68 minutes. Besides four heavy grades, this includes a fifteen mile an hour run for one and a quarter miles out of Jersey City, and slow-ups through Newark, Elizabeth, and South Amboy, and at three drawbridges, three interlocking switch cross-overs, and four grade crossings of other roads. The English locomotive has made this run regularly, and as well in every respect as the best American locomotives can do it. Beyond this its work is improving every day, as the engineers get more accustomed to it. The engineers themselves, and the firemen, naturally don't like it. It has no cab, and although this has been partially remedied by the extension of the little shelter board twenty two inches further back, it is still a very un-

comfortable machine to ride in, especially if it rains. Besides this, its attachments are all different from those in our American locomotive, clumsier and less convenient.

These are matters of detail, however, and have nothing to do with the value of the compound principle, which is really all that is being tested in the engine. The foremen, superintendents, train masters, and others, who are really the authorities to determine as to the success or failure of the new locomotive, are delighted with its performance, and believe that the compound principle will ultimately be adopted for all the Pennsylvania locomotives. This does not mean that locomotives like the English one will be built, but that the English principle of using the steam twice will be adapted to the American style of locomotive, which will not be a difficult thing to do, and will involve no serious alteration in the appearance or conveniences of the American machine. The final test will be made under the direction of the general superintendent of motive power, from Altoona, and will consist of complete and exhaustive experiments to determine just the amount of coal, water, oil, labor, and other things necessary to obtain a certain amount of power from the new locomotive. If these experiments prove what is generally believed by engineers now, that the compound type will produce considerably more power at less cost than the style of engines at present in use, then the compound system will be adopted at once by the Pennsylvania Company and applied to all its locomotives as rapidly as possible. It is likely to be a year, however, before such a step is fully determined upon.

One thing that has been discovered in the use of the Pennsylvania in regular service is that an English locomotive won't stand the wear and tear of American tracks. The engine is too rigid and provided with too short springs to make an easy runner over our roads The racking it gets on rough bits of track makes necessary frequent trips to the shops for trifling repairs.—*N. Y. Sun.*

ON THE LIMIT BETWEEN POLARIZATION AND ELECTROLYSIS.*

Note by M. H. Pellat, presented by M. Lippmann.

Let us designate by M the electromotive force that must be introduced on the circuit which connects the two mercuries of a Lippmann electrometer in order to render maximum the capillary constant of the small mercury. In the case in which the liquid of the electrometer is an acid, I have proved that the electrolysis of this acid is produced as soon as the electromotive force, E, introduced into the circuit is above M. In fact, hydrogen never appears when we get $E < M$, whereas it may appear, with the necessary precautions, as soon as we get $E > M$. We may often considerably exceed the electromotive force, M, without the hydrogen bubble forming; but electrolysis is produced all the same: if the hydrogen does not appear under the gaseous form, it is due to the general law that a gas can only be produced in a visible form in a liquid if there exists a gaseous bubble the diameter of which is above a certain limit; then, most probably, a highly saturated solution of hydrogen will be produced. This extreme saturation is avoided by creating a hydrogen bubble by an electromotive force far higher than M; the electromotive force is then brought back rapidly to a lower value, E; we then find that if E is lower than M, the bubble does not increase in size; whereas, if E is higher than M, the greater the value of $E - M$, the more rapidly does the bubble become enlarged.

This optical method of observing the electrolysis put me upon the track of the phenomenon, but it is not very convenient; I substituted for it a galvano-metrical process, which is susceptible of much greater precision and can be applied much more generally. We introduce into the circuit connecting the two mercury electrodes: (1) E, the electromotive force variable at will; (2) a Thomson galvanometer; (3) an interrupter. Moreover, we take for the small mercury a larger electrode ($\frac{1}{4}$ of a square millimeter). In order to avoid the polarization of the other electrode, we can take a very large surface of mercury; but it is much better to take an unpolarizable system of electrodes (zinc in a salt of zinc); the constant differences of potential thus added to the chain do not signify, since we are only studying variations of electromotive force. The small mercurial electrode is plunged into the same vessel as the point of the capillary electometer which serves to determine M.

We thus find that while E is lower than M, on closing the circuit, the needle of the galvanometer receives an impulse due to the charge of polarization, oscillates, and then becomes fixed at a position very near zero (spontaneous current of depolarization); but as soon as E is above M, the needle undergoes a permanent deviation which is relatively very great and in proportion to $E - M$. The sudden change in the sweep of the curve which represents the intensity of the current as a function of E is very marked.

The truth of the law has been confirmed: (1) By the optical process for sulphuric acid expanded ($\frac{1}{4}$ in volume; $M = 0{\cdot}95$ volt), and for the above mentioned acid with the addition of $\frac{1}{1000}$ of bichromate of soda ($M = 0{\cdot}99$ volt); (2) by the galvanometric process for the same sulphuric acid and for chlorhydric acid ($\frac{1}{4}$ in volume of acid at 21° B.; $M = 0{\cdot}41$ volt).

According to the views of M. Helmholtz, at the moment when the capillary constant is at its maximum, the double electrical layer at the contact of the electrolyte and the mercury is *nil;* the law indicated above may, therefore, be stated thus:

"*Electrolysis commences from the moment when the double electrical layer has been rendered nil by polarization.*"

It is very probable that this law is applicable to any electrolyte whatever. But when it is a metal, *m*, which is rendered free by electrolysis, it forms an amalgam with the mercury of the electrode; this chemical modification of the surface of the electrode transforms the voltmeter, P, into a battery, the electromotive force of which, of contrary nature, increases till it becomes equal to E, which allows of the passage of a very slight quantity of electricity. Thus in the case of the salts E may greatly exceed the value of M, without the needle undergoing any important permanent deviation. However, by increasing more and more the value of E, a moment comes when the needle suddenly takes permanent deviations; the current then passes with an intensity proportionate to $E - K$, designating as K a constant, which is the electromotive force starting from which electrolysis is produced continuously. We gather, in fact, that as soon as there is enough metal, *m*, in the superficial layer of the mercury electrode for this amalgam to act in a battery like the metal, *m*, itself (an amalgam containing less than $\frac{1}{100}$ of zinc acts like pure zinc), the electromotive force of the voltmeter, P, cannot increase any more, and a constant current is produced, in virtue of the constant difference, $E - K$, of the opposing electromotive forces. For $E = M$ the difference of potential is *nil* between the pure mercury and the electrolytic liquid; for $E = K$ the difference of potential is *nil* between the amalgam of the metal, *m*, and the liquid, since the latter is a salt of the metal, *m* (*Comptes Rendus*, April 1, 1889); but the difference of potential is not *nil* between the amalgam formed at the surface of the capillary electrode and the pure mercury further down, and this difference of potential is represented by $K - M$.

For the electrolysis of the sulphate of zinc, we get, in fact, $M = 0{\cdot}76$ volt and $K = 1{\cdot}27$ volts; whence $K - M = 0{\cdot}51$ volt. This last number only differs from the figures 0·49 volt, which I obtained two years ago, for the difference of potential between the amalgam of zinc and the mercury by another method (*Comptes Rendus*, April 1, 1887), by a quantity quite accounted for by the errors of these former experiments. Substituting for the sulphate of zinc the hydrate of potassium, we get $M = 0{\cdot}29$ volt, $K = 1{\cdot}76$ volts, whence $K - M = 1{\cdot}47$ volts. Thus the difference between the potassium and the mercury is $+ 1{\cdot}47$ volts.

If instead of electrolyzing the hydrate of potassium we electrolyze a salt of potassium, we find for $K - M$ different values (1·39 volts with the chloride, 1·41 for the sulphate). But let us remark that the amalgam of potassium formed is attacked by the water, and that in the capillary tube a layer of hydrate of potassium is produced between the electrode and the earth; $K - M$ then no longer represents exactly the difference of potential between the mercury and the potassium: we must add to it the difference of potential between the hydrate of potassium and the salt employed. The truth of this remark is proved by the fact that if we introduce hydrate of potassium between the salt and the electrode of mercury beforehand, we find that the electromotive force which it is necessary to employ, in order that the current may begin to pass continuously, is exactly the same as when the solution of the salt is brought directly into contact with the mercurial electrode. We see by these examples that there is a new method, both general in its application and convenient, for determining the true difference of potential between any metal whatever and mercury. But we also see that in its application we must guard against possible chemical reactions between the metal deposited and the electrolyte.

In a subsequent note we will indicate other methods for arriving at the same object.

* *Comptes Rendus, Electrical Review.*

CONSTANT CURRENT VERSUS CONSTANT POTENTIAL ELECTRIC MOTORS.

To the Editor of the Scientific American:

In your Supplement of July 20, Mr. Frank J. Sprague, in his Sibley College lecture on "Some Applications of Electric Transmission," makes a statement which is somewhat misleading, and as it has a tendency to injure an industry in which we are largely engaged, we take the liberty of calling your attention to the matter. We have designed and constructed a constant current motor which has received the highest encomiums from the very best authorities. We have several of our machines in active use in this city, and we are receiving the very best testimonials of their high efficiency. Mr. Sprague makes this statement in his paper:

"It is hardly necessary for me, it seems, to make any extended comments on the commercial application of motors to constant current circuits; for small powers only on long lines it has a *limited* application, but cannot for a moment compete with a general distribution under constant potential, where perfect independence and large size of motors is secured with safety and economy."

It is an undisputed fact that the transmission of the constant potential under a pressure of 110 volts, which is the pressure of current now in general use, cannot be economically transmitted to long distances, and, unless the pressure is increased to 1,000 volts, or, as Mr. Sprague says, "2,000 volts would be better," the constant current will be utilized by those who desire to use electricity as a transmitter of energy. In proof of our assertion we quote from Professor Silvanus Thompson, an acknowledged authority:

"The method of distribution by a constant current is, where power is to be transmitted to long distances, a much more economical method than that of distribution with a constant potential, owing to the fact that for the former method thinner and, therefore, less expensive conducting wires may be employed. It is, therefore, obvious that in the not very distant future electric power will be distributed over large areas in towns and cities by the arc light current."

Emile Kahn,
Pres. Cincinnati Electric Engine Co.
Cincinnati, O.

TELEPHONIC VIBRATIONS.

Dr. Frohlich attaches a small mirror to the iron plate of a telephone and from this the light of an electric lamp is reflected to a polygonal rotating mirror, from which it falls on a screen. The vibrations of the plate were thus made visible on the screen, and since each side of the polygonal mirror cast its own image, when the mirror was rotated the curves were seen moving over the screen. The more rapidly the mirror was rotated the slower did the curves move over the screen, and when the rotation was as rapid as the vibration of the plate, the curves became stationary and could thus be exactly observed and drawn. These luminous curves could also be photographed. The speaker had employed this method in a series of researches on certain electrical phenomena which might influence the efficiency of the telephone. Thus the action of alternating currents, of self-induction, of the rise and fall of the current on making and breaking, of the introduction of electromagnets, and of other conditions, were studied by means of the altered mode of vibration of the telephone plate. The speaker had further obtained a graphic record of the vibration of the telephone plate when vowels and consonants were sung and spoken into it.—*Physical Soc., Berlin —Nature.*

NEW PRUSSIAN BLUE.

Ordinary Prussian Blue which has been purified by acids in the usual manner may be readily converted into the soluble modification by boiling with potassium ferro or ferri cyanide. The latter is most conveniently prepared by gradually adding to a boiling solution of 110 grms. of potassium ferricyanide a hot solution of 70 grms. of ferrous sulphate. Only one-half of the ferricyanide enters into the reaction. The mixture is now boiled for two hours, filtered, and washed with pure water until the wash water assumes a deep blue shade. The residue is dried at 100°. This blue dissolves readily in water and is very suitable for anatomical injections, as it remains in solution in presence of considerable quantities of gelatin. From the filtrate a further quantity of soluble blue may be obtained by adding 55 grms. of ferricyanide and 70 grms. of ferrous sulphate. If necessary, the soluble blue is freed entirely from ferricyanide by washing with weak alcohol (40 per cent.) Solutions of soluble blue are precipitated by concentrated solutions of sulphate or chloride of sodium.

Pure Soluble Prussian Blue is prepared by digesting an excess of Prussian blue paste with a saturated solution of oxalic acid. The filtrate, after standing for two months, deposits the pure blue, the liquid itself becoming colorless. The color is washed with weak alcohol and dried. It now dissolves readily in pure water. The same result is obtained more rapidly by precipitating the oxalic acid solution with 95 per cent. alcohol, or a concentrated solution of sulphate of soda, and washing the color with weak alcohol. Tartrate or oxalate of ammonium can take the place of the oxalic acids in the above reactions. On boiling the oxalic acid solutions, ordinary insoluble blue is precipitated. Dilute sulphuric acid also precipitates the insoluble modification.

New Solvents of Prussian Blue.—By boiling Prussian blue with molybdic acid, a deep blue solution is obtained which is not precipitated by gelatin, but, on cooling, the solution sets to a transparent deep blue mass. Instead of molybdic acid, molybdate and tungstate of ammonium may be employed.—*C. E. Guignet, in Compt. Rend.*

BLEACHING OF JUTE.

By Oscar Meesters.

To bleach jute pure white, the first condition is that it be as free as possible from adhering particles of rind, because the latter contains a very large proportion of a colored tannin which in boiling dyes the fiber fast yellow brown and thereby renders the bleaching very difficult. If the fiber is reasonably free from this rind, a very fine white can in the simplest manner be obtained by the following method:

About 1,500 lit. cold water are let into a keir, the solution of 10 kil. calcined soda added and well stirred; then 100 kil. jute fiber are laid down in the bath, which is slowly brought to a boil and kept well boiling for at least three hours; then the brown lye is let out, the jute taken up and rinsed in cold water, well drained, and laid down for 10–12 hours in a cold bath of chloride of lime at 3° Bé.

By acidifying the jute previous to chloring, as is usual with cotton, a more rapid but very uneven, hardly acceptable bleach would be obtained, because in this case the chlorine acts at once upon the immediately accessible fiber and has not time enough to uniformly reach the less exposed fine filaments. Without first acidifying, therefore, a slower but much better, evener bleach is obtained.

After lifting the jute from the chlorine bath (which is continuously used for bleaching by fresh additions of solutions of chloride of lime) and allowing it to drain well, it is laid down in a water bath of 144° F., and well rinsed in cold water. Then it is for 1–2 hours laid down in a strongly sour bath of sulphuric acid, and well rinsed. As a matter of course, the white is much improved by repeating the whole process. If it is desired to render the jute quite soft, it may be passed through a bath of Marseilles soap, with the precaution, however, that its temperature must not exceed 122° F., because the tannic acid which may possibly have remained in the fiber would, at a higher temperature, change the white to yellow.—*F. M. Z.—Textile Colorist.*

BLEACHING OF WOOLEN RAGS.

By Dr. A. Horwitz.

The well-known bleaching substance for vegetable fibers, cotton, linen, etc., chlorine, cannot be used for bleaching the animal fibers, wool and silk; because it does not decolorize but rather discolorizes them, colors them yellow. Sulphurous acid is, therefore, the proper bleaching acid for wool and silk. For this purpose the wool, or silk, is moistened and hung up in chambers or boxes, in which sulphur is burned, and this operation is repeated several times, if necessary. In the wetted goods to be bleached is thereby a solution of sulphurous acid produced: the bleach is, therefore, effected by such solution. It is rational, therefore, to employ liquid sulphurous acid, *i. e.*, the solution of sulphurous acid in water, instead of gaseous sulphurous acid. Liquid sulphurous acid, however, on standing for some time absorbs oxygen from the air and is converted into sulphuric acid. Sulphurous acid, therefore, which is kept in vessels containing air or which are badly stoppered, always contains sulphuric acid; and the bleached goods, consequently also containing sulphuric acid, are thereby rendered brittle when dry. Bleaching with sulphurous acid must, therefore, always be followed by most careful washing either in water, or more effectually in a dilute solution of soda or of soap. The extraordinary convertibility of sulphurous acid into sulphuric acid has caused the search for other bodies which, having the same efficiency as bleaching agents, present

the advantage over sulphurous acid of possessing greater stability.

At present sulphite or bisulphite of soda, the latter more generally known by the name of leucogen, is used for bleaching wool. Among the various processes in which sulphite or bisulphite of soda is employed, the most practical is doubtless that in which hydrochloric acid is added in order to accelerate the process and to more rapidly induce the reaction of the salt. For this bleach a wooden tub is filled with a 5 per cent. aqueous solution of bisulphite of soda, 2 or 3 per cent. (of the weight of the salt used) hydrochloric acid added, and the material laid down therein, which can be taken up after the lapse of a comparatively short period, to be dried in the air.

The employment of chromium in combination with sulphuric acid for decolorizing cloth rags is based upon the fact that, when chromium compounds are brought together with sulphuric acid, chromic acid is formed, which readily surrenders its oxygen to other oxidizable bodies. It is essentially an oxidation process, that is, absorption of oxygen by the organic dye-stuffs contained in the cloth rags, which causes a decoloration of the rags by the treatment with chromium and sulphuric acid. Any strongly oxidizing substance, therefore, would be able to replace chromium and sulphuric acid. Permanganate of potash is one of the most strongly oxidizing bodies, but whether and to what extent experiments have been made with it in practice, is not known to me.—*Textile Colorist.*

ON the Canadian Pacific Road, where the snow-sheds are in close proximity, an underground cable is used to secure communication and promptly to locate the site of interruption. At isolated sheds and suspected points very high poles carrying the lines clear of all probable obstructions are employed.

ON WARP WEAVING AND KNITTING, WITHOUT WEFT.*

By Mr. ARTHUR PAGET, of Loughborough, Vice-President.

THERE are three chief methods or principles of making fabric or cloth or tissue from yarns or threads.

The method best known and most used is that of ordinary weaving with a "warp" and a "weft," the warp running longitudinally in the fabric and the weft transversely.

The next best known and probably the next most used is "knitting" properly so called; that is, knitting together, weaving or interlacing one thread, as in hand-knitted goods such as stockings, socks, vests, drawers, and articles of underwear generally. Sometimes in some machines more than one thread is used in knitting; and then it is as it were an interweaving or interlacing of "weft threads," knitted to and fro across the length of the fabric, without any "warp threads" running longitudinally.

The least known and probably hitherto the least used system of weaving is what is known as "warp weaving" or knitting. This system is the weaving together or interlacing or knitting together of a number of "warp threads," woven or knitted together along the length of the fabric, without the use of any weft running transversely.

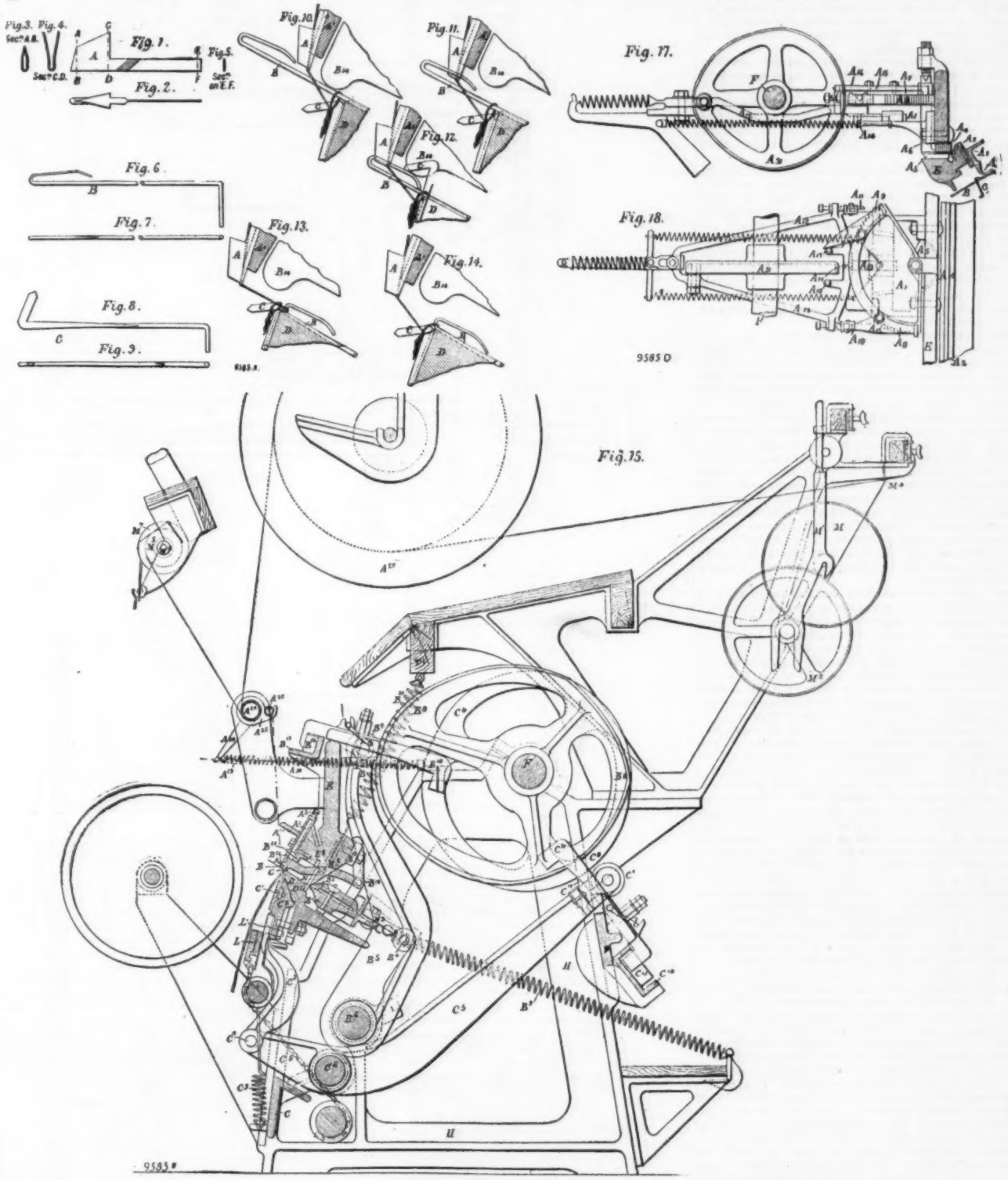
Of course, in ordinary woven fabrics, the fabrics are woven of a certain width in parallel lengths, and the fabric has afterward to be cut and shaped into articles of clothing or whatever shaped articles may be required. Hitherto the only method known of making fabrics which are shaped in weaving them, for articles of clothing and the like, has been by "knitting;" and the fabrics are then shaped (or "fashioned" as it is called in the trade) by methods fully explained in a paper read by the writer at the meeting of this Institution at Nottingham in 1870, and published in the Proceedings for that year (page 127).

In the present paper it will be shown that such shaped goods can now be made by warp weaving or knitting; and a machine which effects this is the special subject of this paper.

In this machine the threads are manipulated or woven or interlaced by the immediate touch or action of three parts, which for convenience are called the three primary parts. These are—the troughs, A, shown in Figs. 1 to 5; the needles, B, shown in Figs. 6 and 7; and the hooks, C, shown in Figs. 8 and 9. There is one of each of these three primary parts to each thread in the width of the fabric to be woven, and at least one additional needle. Thus if the loom is weaving 1000 threads, then for weaving the simplest and most usual fabric there will be 1000 troughs, 1001 needles, and 1000 hooks.

All the warp threads to be woven are ordinarily wound upon a weaver's beam, in the usual manner of preparing a warp for an ordinary loom, and the beam is hung upon an axle in bearings above the warp-weaving machine; or in some cases, as will be described later on, the threads are taken direct from the cops, spools, cones, or bobbins on which the yarn is delivered by the spinner. Each thread of the warp is led downward from the beam, and is passed into and through a trough. In Figs. 10 to 14 these primary parts are shown in five positions in their cycle.

Each trough when at rest is equidistant between the stems of the needles on each side of it, and so that the lowest part of the lips of the lower orifices of the row of troughs are just (and only just) above the tops of the stems of the row of needles. Thus it will be seen that, when the row of troughs is moved sideways (say to the



THE PAGET KNITTING MACHINE AT THE PARIS EXHIBITION.

* Paper read before the Institution of Mechanical Engineers at Paris.—*Engineering.*

left), over and across the row of needles, Fig. 10, exactly as far as the distance between the centers of contiguous needles, each thread will be laid across and over the stem of one needle. The needles then move backward or retire, Fig. 11, so far that the point of the beard of each needle passes over the thread laid upon its stem.

The beard of each needle is then pressed into the eye of the needle, Fig. 13, by a presser (which will be shortly described); while the point of the beard of each needle passes into and safely through the loop of the fabric, Fig. 13, which is on the stems of the needles in front of the hooks. Then the needle retires further, so that its head passes a certain distance beyond the face or front of the row of hooks. Thus a certain length of thread is pulled by each needle against the face of each hook, and through each trough from the beam of warp, and through the loop of the fabric which was on the stems of the needles, and which is drawn over the heads of the needles by the hooks. While the heads of the needles are behind the troughs, the troughs are again moved sideways (this time to the right) into their former position.

The row of hooks is then made to descend, so that the underside of the bend at the top of each hook just presses on each thread; and then the needles are made to advance and the hooks to descend simultaneously, Fig. 14, so that the loops already pulled by the needles are held down by the hooks, while the row of needles continues to advance to their former position. This completes the cycle.

Now if, during the next revolution of the main shaft, the row of troughs were made to pass again over the needles (this time to the left) and then back to their first position as before described, then each needle in the machine would make each thread into a chain, by drawing one loop of each thread through the previously made loop of the same thread; and thus a machine with 1000 needles would make a set of 1000 chains (one chain made of each thread in the machine), but as each chain would be quite independent of the contiguous chain on each side of it, the machine would not make a woven fabric, cloth, or tissue.

But if, after the row of troughs has been made to move one needle to the left, so as to lay the threads over the needles as before described, they are made to move again in the same direction to the extent of one needle more before the needles again come forward to receive a fresh row of loops, then each thread will be passed under the needle next to the left of the needle on which the last loop was formed. Then if the row of troughs be made to move one needle back (to the right), each thread will form a loop on the needle next to the left of the needle on which the first loop was formed. Then if, before the needles again come forward to receive a fresh row of loops, the row of troughs be again moved to the right, each thread will be passed under the needle upon which the first loop was made, ready to form a loop upon it again. Thus each thread forms a loop, first on one needle, then on the one next to it, then back again on the first, and so on. Thus a woven fabric is formed.

In goods made with stripes of different-colored threads, the alternations of a certain number of movements of the troughs to the right, and then a certain number to the left, may be made to produce a number of stripes, either straight or in various kinds of zigzags.

To vary the closeness of the weaving, it is only necessary that the distances to which the row of needles and the row of hooks retire should be varied; thus longer or shorter loops will be pulled by the needles and held by the hooks, and so a more or less closely woven cloth or fabric will be produced. Of course, in an ordinary loom with a warp and a weft, if the closeness of the weaving, or the closeness with which the threads of the weft are laid, were to be altered, the fabric would be woven more or less open, but the width of the fabric would not be appreciably altered. But warp-woven fabrics have a different property or nature; so that, if the machine is weaving a fabric of a certain yarn on a certain number of needles with a certain closeness of weaving (that is, with a certain length of loops), and if the machine be then altered so as to draw slightly longer loops and weave the fabric slightly more open, then the width of the fabric made by the machine is at once materially increased. It is by using this property of the warp-woven fabrics that this machine has been made so as to be able when desired to shape the fabrics while they are being woven, that is, to increase or diminish their width while they are being woven.

We will first follow the movements of the row of troughs, and explain how these are effected. Each trough, A, is attached to the trough bar, A1, Fig. 36, by being driven into a suitable groove, and the walls of the grooves are then partly bent over and partly riveted over, so as to secure the troughs to the trough bar; the trough bar is bolted to the trough slide bar, A2, and this as it were hangs on and slides to and fro upon the V-shaped part of the main bar, E. The trough bars are adjusted by the screws, A3, Figs. 15 and 16, so that the lower lips or orifices of the troughs will just pass over the stems of the needles, as close to them as possible, so as not to touch them, but to allow only sufficient room for the threads to pass between the troughs and the needles. On the back of the trough slide bar, A2, Figs. 17 and 18, there is a toothed rack, A4, into which gears the small segment of a wheel, A5, attached to the spindle or shaft, A6; to the top of the spindle is attached the segment of a ratchet wheel, A7, at the left side of which are ratchet teeth, A8, while at the right side are ratchet teeth, A9, so made as to act contrariwise to the teeth at the left side; the pitches and arrangements of these ratchet teeth on the wheel, A7, and the wheel, A5, and the rack, A4, are such that, when the ratchet segment is moved one tooth to the right, the trough bar is moved one needle to the left, and *vice versa*.

Two chisel-shaped ratchets, A10 and A11, are attached to the triangular ratchet frame, A12, so that, according to the position sideways of the ratchet frame, either but not both of the ratchets (when the triangular frame is moved to and from the main shaft, F, by the cam, A31) will act upon the ratchet teeth, and will move the trough bar either one needle to the right or one needle to the left, in accordance with the position sideways in which the ratchets are held.

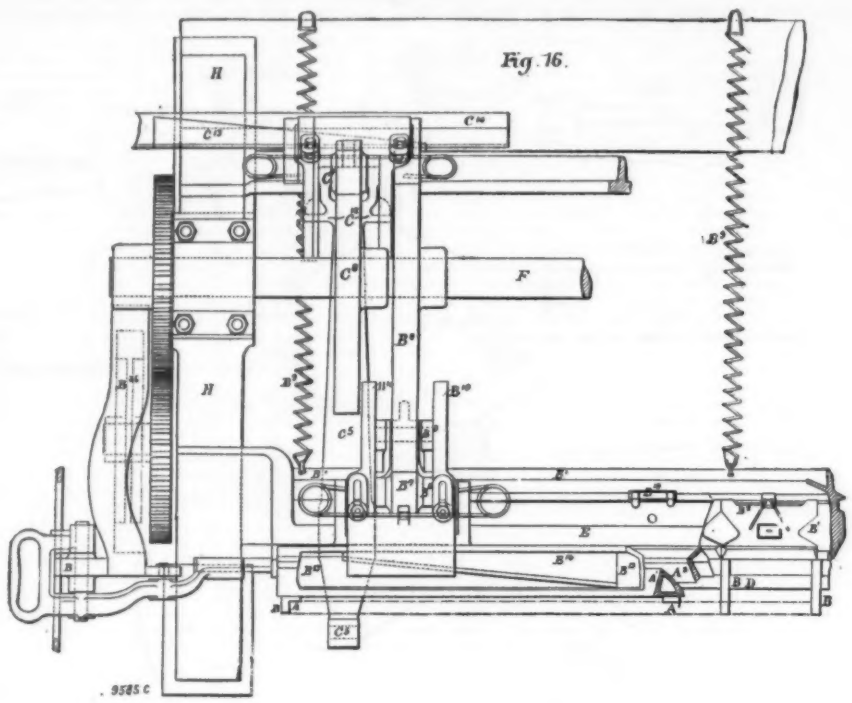
There is a wedge-shaped spring latch, A13, acting upon a wedge-shaped projection, A14, on the ratchet frame, which will allow it to be moved either to the right or to the left, so as to put into action either the right or the left ratchet; and then to keep in action whichever is put into action, until the ratchet frame is moved sideways. To the upper surface of the ratchet segment, A7, at the left side there is attached an inclined finger, A15, and another similar finger, A16, is attached in a similar way to the right side; and these fingers can be adjusted at such a distance from each other that, when the left ratchet has moved the ratchet segment, say two teeth to the left, then, as the ratchet frame is moved backward toward the main shaft, the projection, A17, on the ratchet frame, will come in contact with the inclined finger, and will move the ratchet frame to the right, so that the left ratchet will be put out of action, and the right ratchet will come into action; and then, when the ratchet segment has been moved two teeth to the right, the finger will act upon the projection, A18, and in a similar manner will move the ratchet frame to the left; and so on. Thus the trough bar and troughs will be moved two needles to the right for one revolution of the main shaft, and then two needles to the left for the next revolution of the main shaft; and so on.

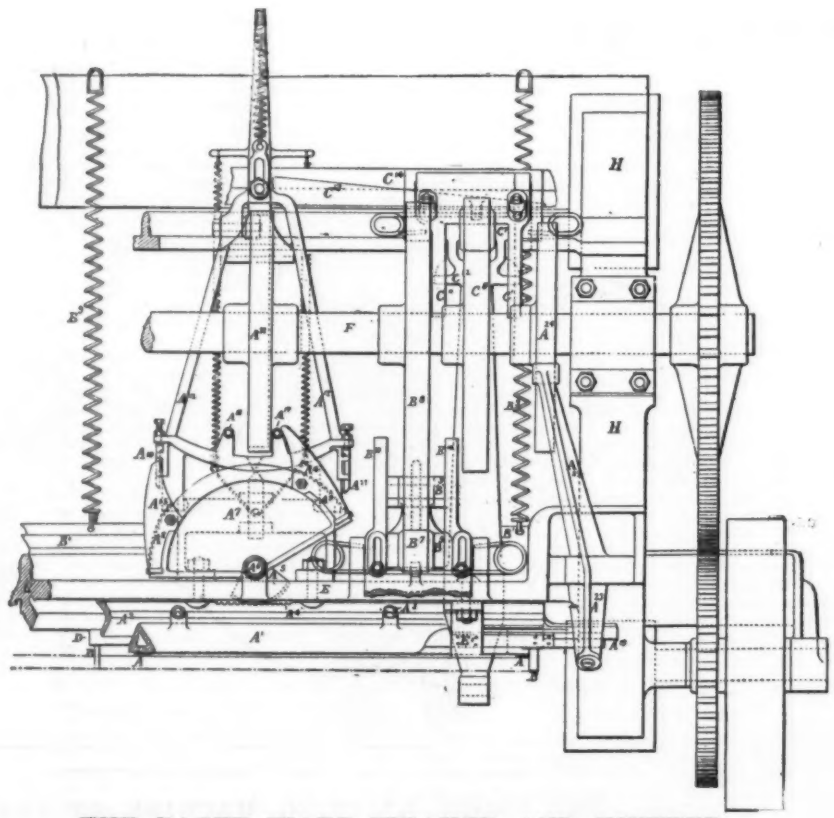
It is of course absolutely necessary that, at the end of each traverse of the trough bar, each trough should stop at and remain at the exact center of one of the spaces between the needles; and this is effected in the following manner. On the front face of the right-hand end of the trough slide bar, A2, Figs. 20 and 21, there is formed a row of wedge-shaped teeth, A19, of the same pitch as the needles of the machine; and facing these a similar set of wedge-shaped teeth, A20, are formed on a bar, A21, which is hinged by a spring hinge at its end, A22, to a projection, E1, on the main bar, E. When the trough slide bar is completing its traverse, the set of teeth on the hinged bar, A21, are pressed toward and against the set of teeth, A19, on the trough slide bar, A2; and the two sets of teeth are so arranged that, when they are engaged and pressed together, the trough slide bar must take and keep its exact longitudinal position. The hinged bar is moved to and from the trough slide bar by the lever, A23, Figs. 19 and 22, which is actuated at the right times by the cam, A24.

There is a further apparatus attached to the machine for enabling the zigzag stripes before mentioned to be made by controlling the movements of the ratchet frame and the trough bar to the left and to the right in certain fixed varying orders; but the description of it would unduly lengthen this paper, and any one wishing can see it and have it explained on the machine in the exhibition, in the British section of the Machinery Hall.

We will now follow the movements of the needles, B, and explain how these are effected. The needles are held at their back ends by hinged plates, B2, which press them into grooves and holes in the needle bar, B1, Figs. 15 and 16; this bar is held at the back by two joints, B3, which are attached by two joint pins, B4, to the two arms, B5, of the rocking shaft, B6; the ends of the shaft are free to oscillate in a rotating fashion in bearings in the end frames or legs, H, of the machine. The upper ends of the two rocking shaft arms, B5, carry two bowls or trucks, B7, each of which is pushed away from the main shaft, F, by a cam, B8; and the bowls are drawn toward the shaft by the springs, B9, which pull the needle bar, B1, backward. Thus by acting through the joints, B3, and the rocking shaft arms, B5,

Fig. 16.



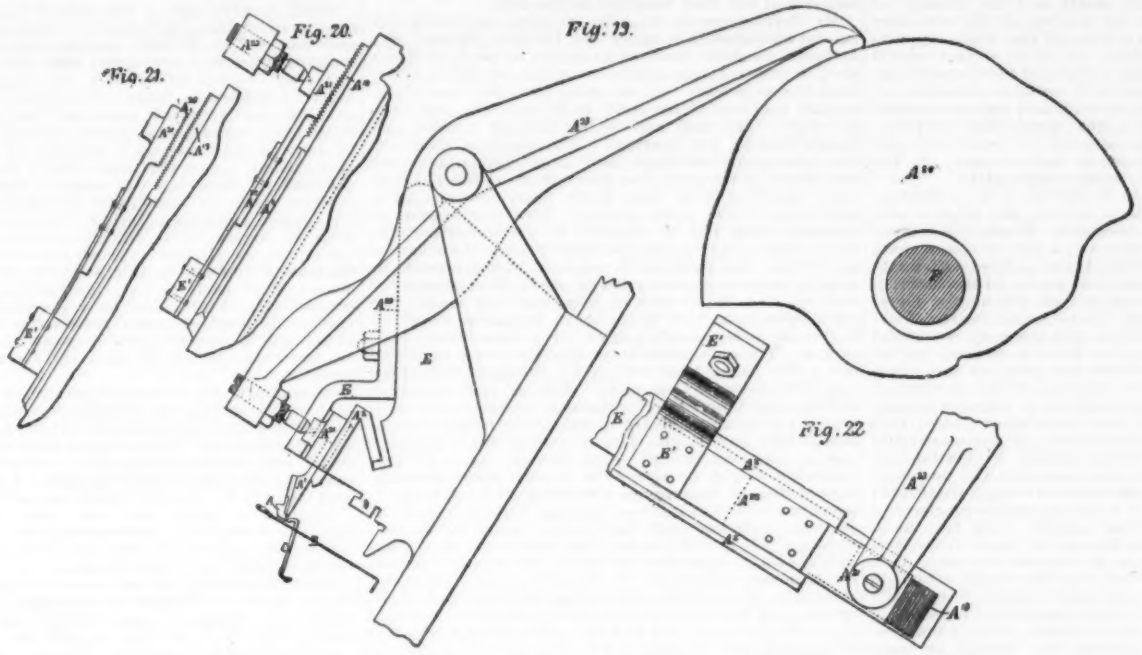


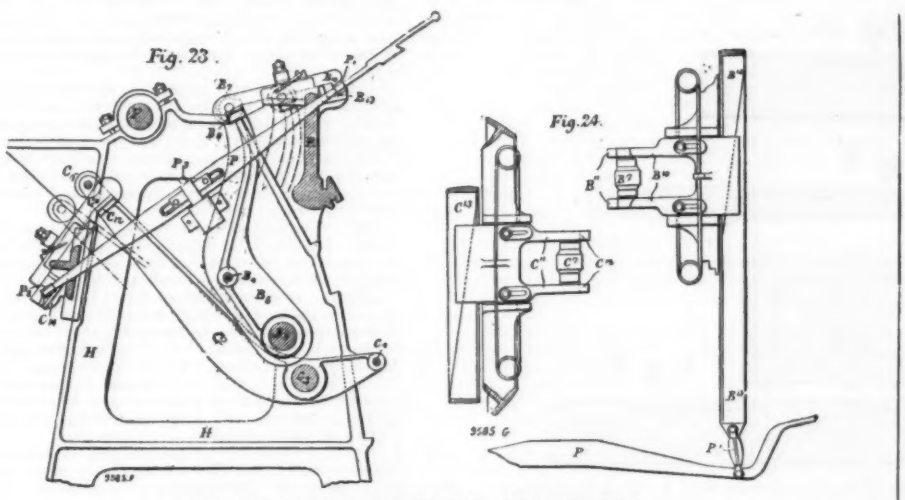
THE PAGET WARP WEAVER AND KNITTER.

these springs keep the bowls, B7, always pulling toward the main shaft, F; and the extent of the movement of the bowls toward the main shaft, F, and of the consequent backward movement of the needle bar, B1, and needles, B, is controlled by two double needle-controlling hooks or stops, B10, which take hold of or stop the four projections, B11, two on each rocking shaft arm, B5. The positions of these two double needle-controlling hooks, B10, are controlled by the action of the two

and slides against the under surface of the main bar, E. If this bar, B23, is traversed endway in the direction of the arrow, B24, it will be seen that by the combined action of the two sets of wedges the presser, B14, will be made to descend; whereas if the bar, B23, is made to traverse in the direction of the arrow, B25, the presser will be caused to ascend by the springs, B20. The traversing to and fro of the bar or rod, B23, is effected by the cam, B26, acting upon the two bowls which are

It is necessary, therefore, in order to enable a machine of this class to make cloth in one width (of 7 feet as in this machine), that the bar, E, and the bar, D, should be held together very firmly and very strongly, without in any way interfering with the continuity of the row of needles, A. It will be seen by reference to Figs. 15 and 36 that this is effected by the connectors, N, which are made of steel plate of the shape shown, each being thin enough to pass easily between any two needles in





THE PAGET KNITTING MACHINE.

wedges, B12, which are attached to the bar, B13, that slides longitudinally in suitable slides or bearings attached to the machine. Thus it will be seen that, by sliding the bar, B13, and its wedges, B12, to and fro longitudinally, the distance of the backward movement of the needles is easily controlled.

The front ends of the needles rest upon and slide on the grooved top of the knocking-over bar, D, which is held at each end by the legs or framings, H, of the machine.

We will now follow the movements of the presser, B 14, and explain how these are effected. When the needles have moved backward so far that the points of their beards are safely over the threads laid upon the stems of the needles, then the presser, B14, is caused to descend, so that its rounded lower edge, B15, presses upon the beards, Fig. 12, and holds their points down in the eyes of the needles, until the points of the beards are safely entered into and have passed through the loops last made of the fabric. The presser then ascends, so as not to touch the needles or their beards; and it remains in this raised position until the needles have come forward, and the troughs are again about to traverse across the needle stems. Now it is evident that, if a needle should be slightly strained and raised, so that it does not rest upon the bottom of its groove in the knocking-over bar, D, the trough which has to traverse over this needle might push the needle stem to one side and break the needle, and possibly also the trough. In order to prevent this, before the troughs traverse over the needle stems the presser, B14, is made to descend and press all the needle stems down against the bottom of the grooves in the knocking-over bar, D, Fig. 10, so that then all the troughs can safely traverse over all the needles; and when they have done so, the presser then ascends again, so as to be clear above the needle beards until they have again retired to the right position for being pressed.

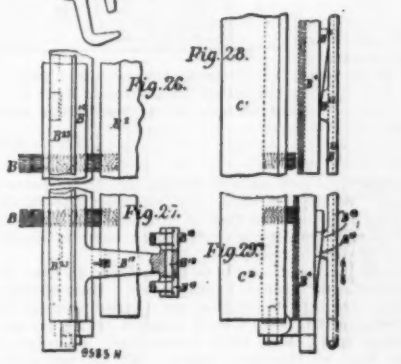
The presser, B14, has six arms, B17, which project backward and under the main bar, E, Figs. 15 and 16, and are hinged by pivots, B18, to brackets, B19, which are attached to the back of the main bar, E. Springs, B20, attached at the lower end to the arms, B17, and at the top end to a suitable bar, T, tend always to lift the presser upward.

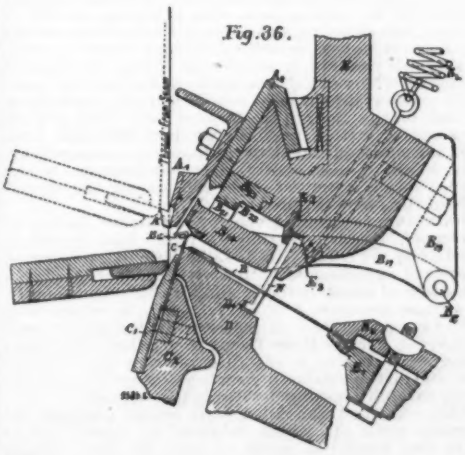
On the top of the presser, B14, are formed some wedge-shaped surfaces, B21, Figs. 25 to 29; and acting upon these are other wedge-shaped surfaces, B22, formed on the bar or rod, B23, the upper surface of which rests

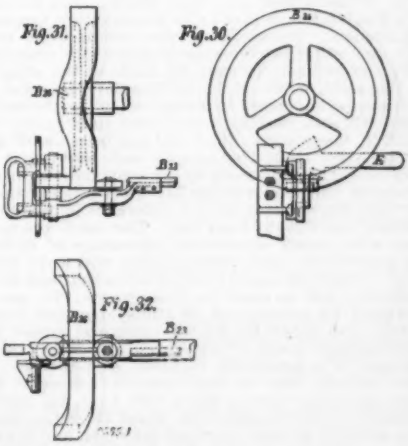
shown at the end of the bar, B23, in Fig. 16 and Figs. 30 to 32.

It will be seen that the wedges which actuate the presser, B14, have a strong tendency to bend or curve the main bar, E, upward between its two ends, where it is secured to the main framing, H, of the machine. The presser also has a strong tendency to force downward and to curve downward in a similar manner the knocking-over bar, D; for, although the power required to press the beard of one needle into its eye is small, the power required to press the beards of the whole 1,008

the row. The upper ends of these connectors, N, hook into a groove, E2, in the main bar, E, and are held there by a piece of brass, E3, and by solder. The hook at the lower end of the connector, N, hooks into a groove, D1, in the knocking-over bar, D. It will thus be seen that, in order to hold together with great firmness and rigidity the main bar, E, and the knocking-over bar, D, and thus to prevent these two bars from







THE PAGET KNITTING MACHINE.

needles into their eyes is very large. If the combined curvature of these two bars were to amount in the middle of the width of the machine to as much as $\frac{1}{32}$ in. (that is $\frac{1}{100}$ in. for each bar), this would be sufficient to make the difference between pressing the beards thoroughly and properly and entirely failing to press them.

being sprung apart, and thus to insure the accurate and perfect pressing of all the row of needles, B, it is only necessary to insert a sufficient number of these conectors, N, between the needles, at convenient distances apart across the whole width of the machine.

(To be continued.)

THE LIBBY COMPOSITE BARS.

This invention is by Robert H. Libby, of Boston, Massachusetts. The object is to provide a simple and easy means of producing car axles, shafting, and other metal articles having sections thereof solid throughout and sections of tubular or cylindrical form, or in the form of a shell connecting the solid sections, and integral therewith.

In the manufacture of car axles the solid sections occur at the ends of the shafts, and the tubular or cylindrical sections form the portion of the structure between. In shafts the portions of the shaft supporting the pulley, gear wheel, or other device should be solid and the remaining sections of tubular or cylindrical form. The disposition of metal in structures of this character in alternating solid and tubular or shell form is very desirable for a great many other purposes, and especially where it is essential to obtain strength with comparative lightness in certain parts of the structures and solidity in certain other parts.

From a report by Mr. G. E. Betton, C.E., of Boston, this process appears to be a peculiar and original one, and may be thus briefly described: When it is desired to apply it to steel manufacture, a case or box of sheet iron is made of the size desired; this is filled with finely powdered silica or fine sand and placed in the mould a few inches from the bottom, so that the melted metal will run under and around its sides to the desired thickness. The metal is poured in and the work continued until the box containing the silica is covered on the top as well as on the bottom and sides, so that when the process is completed it contains within it the box of silica; the ingot is now ready to be manipulated as if it were solid steel, and can be rolled or drawn to a rod of less than one inch in diameter, or hammered into flat plates or any other form desired. No matter how finely drawn or flattened, the sand core will be found in the center with the steel covering evenly distributed over it. The sand core, it is found, has the property of expanding and contracting equally with the metal covering it, so that when the article made from it is completed, it is found to be so compact and solid as to give additional strength and rigidity to the article in which it is situated. This property makes it especially valuable when used for pillar supports or beams in building, for in cases of fire the core, being a non-conductor of heat, would prevent the column or beam from getting hot enough to impair its usefulness and safety. By this process, by varying the method of making the core, so that it can be withdrawn, tubing of superior quality and strength can be made, even common gun barrels.

When the sand core is to be inclosed in iron, a somewhat different process is employed. Bars of iron of the proper size and thickness are placed around the can containing the silica, and heated in a furnace to a melting heat, and then hammered or rolled in the same way as the steel ingot. Mr. Betton states that some of the oldest and best known iron workers in New England have given this process their unqualified indorsement. Speaking of the comparative cost of rails and other products made under this process, the sand core rail can, he says, be made at the same price as the solid, while, it being tubular, the tube filled with sand compressed by being rolled in the rail adds great stiffness, making a 70 lb. rail fully equal to one of 100 lb. made solid. This rail can be made of higher carbon steel than the present rail, making it more durable. This rail being 25 per cent. lighter in consequence of the core, will lay 25 per cent. more track per ton than the solid, making a difference in favor of the sand core of about $8 per ton. The sand core rail will bear with safety double the percentage of carbon of the present rail, and, consequently, will wear twice as long. There are many other articles that can and undoubtedly will be made by this process, viz., car axles, line shafting, columns of all kinds, structure bars and beams, gun tubes for heavy ordnance, armor plates, fortifications, fireproof buildings, etc. For structural columns it is especially valuable, as can be shown by tests already made by a government officer at Watertown arsenal, where a bar 4 feet long, 4¼ inches in diameter, with 2⅝ sand core, stood 228,000 lb. compression on ends without starting the scale, and 324,000 lb. with a deflection of 1⅛ inch. A solid bar of the same size would start the scale at 100,000 lb., and a solid cast iron column would break at 120,000 lb. A tubular shaft with a core has a great factor of safety by having the metal center removed, so there is not any metal center to crystallize and cause the shaft to break before it is half worn out. A car axle made by this process has 100 per cent. more strength than a solid, and 200 per cent. more safety by having the cause of crystallizing removed from the center of the shaft. The tube that was used for government test has 35 per cent. less metal than the solid bars, showing that 65 per cent. of metal tube with the sand core can stand 200 per cent. more compression than 100 per cent. all metal of the same size. For a line of shafting 40 per cent. of core can be used, making a ton of either iron or steel shafting cost in America no more than $5 or $6 above the cost of solid, while it will give about 40 per cent. more length, with the great gain of strength and safety from breaking by vibration that would be generated if the center had not been removed by the core.

Mr. Betton goes on to refer to other articles which can be manufactured under Mr. Libby's process. For instance, he states that car axles can be made of either steel or iron with the sand core which are much stiffer than the solid ones. At the same time they are 100 lb. lighter, and cost 15 per cent. to 30 per cent. less than the solid. The ends can be left tubular or solid, any length desired for bearings. The columns made by this process for buildings have great advantage over any other, as the sand core gives great additional stiffness, enabling it to bear more than double that of solid iron of the same quality. This core retains its stiffness when hot, as the core is a non-conductor of heat, preventing the heat passing through the columns as if solid. For columns 40 per cent. to 50 per cent., or even 60 per cent., of core can be used. This makes the cost not over 75 per cent. of what cast iron costs. Armor plates from 12 to 20 inches in thickness would be better and very much lighter with core from 4 to 10 inches. The core would form a cushion that would resist a shot better than solid metal, the sand itself being a greater resistant than metal. For any purpose where stiffness combined with lightness is desirable, this system is well adapted, as the metal can be rolled or hammered into any shape. For a marine shaft this process is adapted, as an ingot can be made of any desirable weight or size, with a core corresponding, then rolled or hammered the same as a solid ingot, leaving the core in it, thus making the shaft some 25 per cent. to 30 per cent. lighter, and much stiffer and stronger. It is well known that the center of a shaft or bar of any considerable size is not worked by rolls or hammer, therefore, is of not much value for strength. If a certain percentage was taken out of the center, and the shaft hammered on a mandrel, it would be much stronger than if solid. This core works like a mandrel, and by leaving it in, it adds to the stiffness of the article. Blocks of any size can be furnished for buildings for fortifications superior to any other material now in use. An absolute fireproof building of any desired height can be constructed under this process.

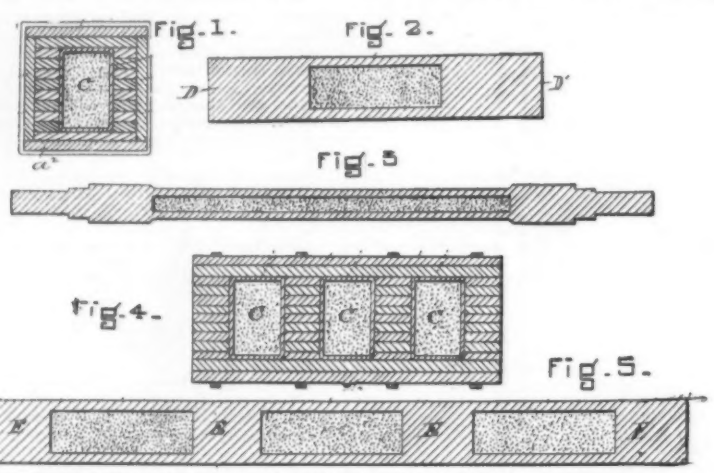


Fig. 1.—Cross section of a box pile. Fig. 2.—A bar made from Fig. 1. Fig. 3.—A car axle rolled therefrom. Fig. 4.—Another form of box pile. Fig. 5.—A bar made therefrom. C represents the sand core.

THE LIBBY COMPOSITE BARS.

CONDENSATION OF CARBON PARTICLES IN SMOKE.

By R. Irvine, F.R.S.E., F.C.S.

In the manufacture of lamp black hydrocarbons are burned in an atmosphere with a limited supply of oxygen; the resulting dense black smoke is conducted into large chambers, where on account of the extremely sluggish draught it is allowed to roll about until the particles, by attraction between themselves, gradually coalesce into masses, which after a lengthy period fall on the floor in the form of soot. This process is exceedingly slow, and the product obtained, from even an enormous condensing space, is comparatively very small. Consequently this manufacture is one carried on on a limited scale, considering the magnitude of the plant required.

Following the lead given by Professor Lodge, of Liverpool, in his experiments upon lead stythe, I, assisted by my friend Mr. J. Lillie Mitchell, undertook a series of experiments with a view to more rapid condensation of smoke carbon; and for this purpose erected a glass structure 5 ft. × 4 ft. × 4 ft., in which were fixed two malleable iron plates, provided with a great number of points—these facing each other; the plates being separated by a distance of from two to three feet, and all the conducting surfaces except these points being carefully insulated with shellac varnish.

This chamber was filled with smoke produced by burning pitch oil, which retained its opacity for at least two hours; so much so that on then looking through the chamber, a bright light placed on the other side was totally obscured by the vapor. The chamber was now refilled with smoke, and the whole atmosphere therein was to a greater or less degree electrified by coupling the conductors which were connected to the plates with a small dynamo. The effect immediately produced was exceedingly striking, the minute particles of carbon at once separated from the opaque smoke, and were attracted to or driven from the points of the plates, congregating together in a most extraordinary manner; and in the space of two or three minutes the atmosphere in the glass chamber was almost entirely cleared of smoke. The prohibitory cost of electricity has, however, prevented the application of this process on the large scale, for the present at least.

ALLOYS OF NICKEL AND STEEL.*

By James Riley, Glasgow.

Some months ago I was asked to examine some specimens of manufactures of various alloys of nickel and iron. The British patents obtained for these manufactures had previously been submitted to me, but their consideration had not caused me to feel much interested in them. When, however, at the request of my friends, I examined the products themselves, my interest was much excited, and with the consent of my directors, I entered on a course of investigations regarding these alloys which is still in progress. I fear that the paper I have been able to prepare must be considered premature, and perhaps incomplete and disappointing; but since I was honored with the request of the council to prepare this paper, I have done my utmost to push our investigations to a conclusion. With the able assistance of my colleagues, Messrs. Dick and Packer, this has been so far accomplished that I am now in a position to submit for your consideration some interesting facts, which I think will probably have a great and lasting effect on the manufacture of steel and its various applications.

In commencing our investigations, it was arranged that before attempting the manufacture of nickel steel ourselves a few ingots should be sent us for treatment and examination. These ingots were of comparatively small size, having been cast from crucibles. They were 4½ in. square, and contained 3 per cent., 5 per cent., and 25 per cent. of nickel respectively.

Samples of plates and bars from these ingots are before you, but it is not necessary to give you details of the tests applied to them, as the results of them will be embodied in my later remarks.

Some time after the conclusion of these tests, a visit to the works in France was arranged to admit of our seeing the process of manufacture and the degree of certainty with which the desired products could be obtained from the crucible. This was demonstrated to our entire satisfaction, a number of casts being made, the composition being varied at will, and the qualities and properties of the metal being indicated beforehand. Samples of these casts were brought to our works and tested.

Subsequently, the patentee visited our works, and charges were made which showed that the composition of the metal can be as effectually controlled in the open hearth furnace as in the crucible.

I have thus briefly sketched the history of our connection with this new alloy, and will now proceed to state the results we have obtained and the conclusions at which we have arrived.

The alloy can be made in any good open hearth furnace working at a fairly good heat. The charge can be made in as short a time as an ordinary "scrap" charge of steel—say about seven hours. Its working demands no extraordinary care; in fact, not so much as is required in working many other kinds of charges, the composition of the resulting steel being easily and definitely controlled. No special arrangements are required for casting, the ordinary ladles and moulds being sufficient. If the charge is properly worked, nearly all the nickel will be found in the steel—almost none is lost in the slag, in this respect being widely different from charges of chrome steel.

The steel is steady in the mould, it is more fluid and thinner than ordinary steel, it sets more rapidly, and appears to be thoroughly homogeneous. The ingots are clean and smooth in appearance on the outside, but those richest in nickel are a little more "piped" than are ingots of ordinary mild steel. There is less liquation of the metalloids in these ingots, therefore liability to serious troubles from this cause is much reduced. Any scrap produced in the subsequent operations of hammering, rolling, shearing, etc., can be remelted in making another charge without loss of nickel. The importance of this fact will be at once appreciated, especially by users of articles made of this metal, seeing that scrap and old articles will have a value for remelting in proportion to their contents of nickel.

No extraordinary care is required when reheating the ingots for hammering or rolling. They will stand quite as much heat as ingots having equal contents of carbon but no nickel, except perhaps in the case of steel containing over 25 per cent. of nickel, when the heat should be kept a little lower and more care taken in forging.

If the steel has been properly made, and is of correct composition, it will hammer and roll well, whether it contains little or much nickel; but it is possible to make it of such poor quality in other respects that it will crack badly in working, as is the case with ordinary steel.

In endeavoring to obtain a correct idea of the value or usefulness of alloys of nickel and iron or steel, we shall find it of use to consider their behavior under tensile and other mechanical tests, and if these were sufficiently numerous, our task would not be a very difficult one.

If it be remembered, however, that in the composition of nickel steel we have present nickel and manganese and iron, with carbon, silicon, sulphur, and phosphorus, and that even a very small difference in contents of some of these has a considerable influence on the character of the alloy, it will be evident that several series of tests (involving a very large number of separate experiments) are necessary to a full investigation. For instance, we all know the effect of very small increments of carbon in steel; hence to estimate correctly the influence of the addition of nickel, the carbon (as well as manganese and other contents) should remain constant. Then that contents of nickel should be constant and the carbon, etc., varied. Further, that the subsequent treatment of all the products should be identical in every particular. I have not been able to carry out such an elaborate series of tests, but I beg to submit a few test results which will no doubt be of service at this time.

* Paper read before the Iron and Steel Institute.

TABLE I.—TESTS OF STEEL WITH VARYING CONTENTS OF NICKEL.

E. L. = Elastic limit. B. S. = Breaking strain. C. A. = Contraction of area.

Mark.	Composition per cent.			Tensile Tests as Cast.					Tensile Tests as Cast and Annealed.					Tensile Tests as Rolled.					Tensile Tests as Rolled and Annealed.					Remarks.
	Ni.	C.	Mn.	E. L.	B. S.	Extension per cent. in		C. A.	E. L.	B. S.	Extension per cent. in		C. A.	E. L.	B. S.	Extension per cent. in		C. A.	E. L.	B. S.	Extension per cent. in		C. A.	
						8 in.	4 in.				8 in.	4 in.				8 in.	4 in.				8 in.	4 in.		
	p. c.	p. c.	p. c.	Tons.	Tons.			p. c.	Tons.	Tons.			p. c.	Tons.	Tons.			p. c.	Tons.	Tons.			p. c.	
1*	1·0	0·42	0·58	....	....	....	....	....	27·3	54·6	....	1·5	9·5	32·1	57·6	....	11·0	24·0	30·1	55·1	....	18·7	45·0	
2†	2·0	0·90	0·50	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
3	3·0	0·35	0·57	19·8	34·9	....	2·5	5·6	24·0	34·9	....	2·5	9·0	31·4	51·0	....	20·3	37·0	28·0	48·5	..	29·3	42·0	
4	3·0	0·60	0·26	....	....	....	....	....	....	....	....	....	....	29·4	51·5	9·0	10·1	9·0	30·3	42·9	7·5	9·0	12·0	
5†	4·0	0·85	0·50	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
6	4·7	0·22	0·23	....	....	....	....	....	.. ..	....	....	....	....	25·1	40·5	17·75	23·4	42·0	28·0	40·6	20·0	25·0	44·8	Average reduced by one piece, giving low result.
7	5·0	0·30	0·30	....	....	....	....	....	....	....	....	....	....	30·0	46·4	10·0	12·5	22·5	28·0	42·6	15·0	17·5	18·5	
8	5·0	0·50	0·34	....	....	....	....	....	....	....	....	....	....	31·1	52·0	14·0	15·6	14·0	32·5	46·8	13·5	14·0	17·0	
9‡	10·0	0·50	0·50	..	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	
10	25·0	0·27	0·85	....	....	....	....	....	....	....	....	....	....	38·2	51·4	10·5	11·7	....	12·75	45·8	29·0	30·0	28·6	
11	25·0	0·82	0·52	....	....	....	....	....	....	....	....	....	....	22·0	47·6	43·5	47·6	60·0	15·1	42·1	40·0	45·3	43·6	
12	49·4	0·35	0·57	....	....	....	....	....	....	....	....	....	....	30·5	37·4	....	12·0	24·0	21·0	37·0	....	20·0	29·0	

* Test piece defective. † Too hard to machine with Mushet steel. Makes a fine tool tempered at dull red in boiling water. ‡ Too hard to machine. Makes a good cutting tool when tempered in cold air blast.

In Table I. there are several points of interest which it is desirable to notice.

1. In No. 6 test the carbon present (0·22) is low enough to enable us to make comparison with ordinary mild steel, which would give (when annealed) results about as follows: E. L. 16 tons, B. S. 30 tons, extension 23 per cent. on 8 in., and contraction of area 48 per cent. Therefore in this case the addition of 4·7 per cent. of nickel has raised E. L. from 16 up to 28 tons, and the B. S. from 30 up to 40·6 tons, without impairing the elongation or contraction of area to any noticeable extent. In No. 3 tests somewhat similar results are found, with an addition of only 3 per cent. of nickel, combined with an increase of the carbon to 0·35 per cent.

2. In Nos. 2 and 5 tests there is extreme hardness, due in part to the large quantity of carbon present, but also to the presence of nickel in addition. In No. 9 test, with the carbon very much reduced, this characteristic of hardness is intensified by the increase of nickel to 10 per cent.

This quality of hardness obtains as the nickel is increased, until about 20 per cent. is reached, when a change takes place, and successive additions of nickel tend to make the steel softer and more ductile, and even to neutralize the influence of carbon, as is shown in No. 11 test, in which there is 25 per cent. of nickel and 0·82 of carbon. In this matter of hardness, due to increased increments of nickel, there is some resemblance to manganese steel, as described in Mr. Hadfield's admirable paper; but I am glad to be able to state that before the region of extreme difficulty of machining is reached, we have qualities of nickel steel available which will be of the utmost value for a very large number of purposes.

3. In the 25 per cent. nickel steel there are some peculiar and remarkable properties. In the unannealed specimen the B. S. is high and the E. L. moderately so, but in the annealed piece, while the B. S. remains good, the E. L. is very greatly reduced, down to one-third of the B. S. Again, in both cases, the ductility as shown by the extension before fracture is marvelous, reaching 40 per cent. in 8 in. Another feature (clearly brought out in tests Nos. 10 and 11, most in No. 10, by the small contraction of area) is that this elongation is nearly uniform throughout the piece.

Before leaving this class of tests, I may state that a very large series of hardening and tempering tests, which I have had made, but which I am not prepared to submit at present, show the possibility of very largely raising the B. S. and E. L. and the hardness of these alloys. We have tested pieces up to 87 tons B. S. with 52 tons E. L.; but there is a piece before you—furnished by the patentee—which was tested by us, and gave B. S. 95·6 tons, E. L. 54 tons, extension in 4 in. 9·37 per cent., contraction of area 49·2 per cent. Two similar pieces, tested by Mr. Kirkaldy, gave B. S. 94·18 and 93·86 tons, E. L. 52·01 and 53·92 tons, extension 7·8 and 8·2 per cent., and contraction of area 52·4 and 50 per cent. respectively.

Permit me now to invite your attention to Table II., which gives results of torsion tests. In the right hand column, headed "Remarks," is given the number of sample or test in Table I., for reference as to tensile strength, etc. The torsion tests have been made on the steel in the condition in which it left the hammer, and also after having been annealed.

I have arranged both classes in what we consider order of merit, having regard to all the three qualities of B. S., E. L., and ductility, as shown by number of twists borne by each. It is satisfactory to find that to obtain the best results it is not necessary to use the steels rich in nickel, as only 1 per cent. is present in that which stands first in both classes.

There are several interesting points in this table to which I would ask your consideration. 1. At the foot of it I give results of torsional tests on Siemens steel. Nos. 7 and 8 are tests of the same steel annealed and unannealed, having a tensile strength of 47·2 and 50·4 tons respectively. A comparison of these two shows a very slight improvement in ductility due to the annealing. Now compare them with No. 9, which is a test of ordinary mild steel of 30 tons tensile strength, and it will, I think, be concluded that it would be better to sacrifice some of the ductility shown by the greater number of twists, in order to obtain some of the greater strength shown in the higher E. L. and B. S. of Nos. 7 and 8. It has become common to order propeller and other shafts of mild steel, but I am inclined to the opinion that their resistance to both stress and wear would be increased by the use of stronger steel, while still leaving an ample margin of ductility. But this is incidental.

2. I would ask you next to compare the results obtained with the ordinary steel with those of the nickel steel, and I think there will be no hesitation in deciding that there will be a very great advantage gained by the use of the latter—advantage either in reduction of scantling or in increased strength and ductility.

3. It is interesting to notice how very closely this series of tests confirms those in Table I., the E. L. and B. S. in both annealed and unannealed samples corresponding, and having the same relation to each other in both systems of tests, while the number of twists corresponds closely to the ductility as measured by extension in the tensile tests.

There are a few other properties of these alloys to which I will briefly refer. The specific gravity of nickel is given as 8·66 (we make it 8·86); that of ferro-nickel, if 25 per cent. nickel, 8·08; that of 10 per cent. nickel, 7·866; that of 5 per cent. nickel, 7·846; while the mean of our results of hammered steel is 7·84.

The whole of the series of nickel steels up to 50 per cent. nickel take a good polish and finish, with a good surface, the color being lighter with the increased additions of nickel.

In the very important matter of corrodibility, it is with the greatest satisfaction I can state that the steels rich in nickel are practically non-corrodible, and that those poor in nickel are much better than other steels in this respect. Thus some experiments we have made show that, as compared with mild steel of 0·18 carbon, 5 per cent. nickel steel corrodes in the ratio of 10 to 12, and, as compared with steel having 0·40 carbon, with 1·6 chromium, in that of 10 to 15. In the case of 25 per cent. nickel steel, these ratios are as 10 is to 870 and 10 to 1,160 respectively. These results were obtained by immersion of samples of the different steels in Abel's corrosive liquid, and the results confirmed by subsequent immersion in water acidified by hydrochloric acid. Some samples of the richer nickel steels which have been lying exposed to the atmosphere for several weeks still show an untarnished fracture.

The alloys up to 5 per cent. of nickel can be machined with moderate ease; beyond that strength they are more difficult to machine. The poorer ones stand punching exceedingly well, both as rolled and after annealing. The punch holes can be put as close together as ¼ in. without the metal showing any signs of cracking.

The 1 per cent. nickel steel welds fairly well, but this quality deteriorates with each addition of nickel.

The poorer alloys do not show any luster, but the richer ones have a lustrous appearance when the scale is removed.

I do not think I have anything more to add as to the properties and qualities of these alloys, but it may be interesting to state the theory held by the inventors regarding their formation. They state that they adopt M. Chernoff's view of steel—that it is composed of crystals of metallic iron cemented together by carbide of iron—and they account for the extra strength given to steel by nickel by its alloying with this carbide of iron to form a stronger "cement;" that the space between the crystals of iron is thus more completely filled, and the cohesion between them rendered much more powerful; that the points of solidification of the cement and crystals are nearer, producing or maintaining a more intimate interweaving of the elements; that their process of manufacture is necessary to cause the nickel to enter into combination and produce a homogeneous alloy, as without it there would only be formed a mechanical mixture, not possessing homogeneity, malleability, or ductility.

TABLE II.—TORSION TESTS.

Mark.	Number of Twists in 3 in. Length	Diameter of Bar 1 in. Lever 1 ft. long. Weight in Pounds.		Condition.	Composition per cent.			Remarks.
		Elastic Limit.	Breaking Strain.		Ni.	C.	Mn.	
1	1¾	857	1849	As hammered.	1·0	0·42	0·58	No. 1 sample in No. 1 Table (unannealed).
2	2⅝	677	1507	"	5·0	0·30	0·30	No. 7 " " " "
3	1⅜	665	1729	"	3·0	0·35	0·57	No. 3 " " " "
4	1⅞	621	1495	"	4·7	0·22	0·23	No. 6 " " " "
5	2⅝	553	1554	"	50·0	0·35	....	
6	3	510	1950	"	25·0	0·27	0·85	No. 10 " " " "
1a	1¾	697	1809	Annealed.	1·0	0·42	0·58	No. 1 " " " (annealed).
2a	2⅝	653	1485	"	5·0	0·30	0·30	No. 7 " " " "
4a	2⅝	652	1443	"	4·7	0·22	0·23	No. 6 " " " "
6a	5	360	2100	"	25·0	0·27	0·85	No. 10 " " " "
7	1¼	601	1689	"	....	0·51	....	47·2 tons per square inch, Siemens steel.
8	1⅝	601	1697	As hammered.	....	0·51	....	50·4 " " " "
9	3⅛	445	1229	"	....	....	....	30·1 " " " "

In concluding, I may be permitted to indicate some of the possible uses to which these alloys may be applied. It requires no powerful imagination to conjure up a most bewildering number of applications for which they are available. I find some difficulty in not becoming enthusiastic on the point, for in the wide range of properties or qualities possessed by these alloys, it really seems as if any conceivable demand could be met and satisfied.

Of the richer alloys I do not intend to speak at any length, but would just remark that in the immense field covered by what are termed the "metal trades," innumerable applications will be found for which they are suitable. Some specimens of these applications are before you.

Of the 25 per cent. nickel steel I would remark that with its peculiar properties of high B. S., great ductility, and comparatively low E. L., it is extremely well adapted for all operations involving considerable deformation—for instance, for deep stamping and flanging—while its non-corrodibility will render it invaluable for a great number of purposes.

This quality of non-corrodibility, considered with its strength, both elastic and ultimate, when unannealed, will render it specially useful in all cases where the cost of metal is of minor importance when contrasted with the cost of labor to be expended upon it, or its use for special purposes; illustrations of these may be found in all small and special type boilers, in locomotive and other fire boxes, and in the hulls of torpedo and other similar vessels, where lightness and strength with non-corrodibility are of vital importance.

In the region between 25 per cent. and say 5 per cent. nickel we have an abundance of possibilities as yet comparatively unknown, in which I expect will be found materials for tool steel equal, if not superior, to anything at present known.

But it is when we get to the alloys of 5 per cent. and under that I feel most interested, and I think most of you will sympathize with that feeling.

I have already incidentally referred to the advantages the marine engineer will obtain by the use of these qualities for the shafts and other forgings used in his structures. I would now point to the suitability of these lower alloys to the other portions of his work. It is well known—it has been frequently stated by my friend Mr. Parker and others—that the recent advances in marine engineering, rendered possible by the use of high pressure steam, could not have been effected if it had not been that a metal superior to wrought iron was put at the engineer's disposal. Conceive then of the possibilities now presented when a metal like No. 6 in the table No. I. is at his disposal, having, when annealed, an ultimate strength of 30 per cent. and elastic limit of 60 or 70 per cent. higher than those of mild steel, with a nearly equal ductility, and the valuable quality added of less liability to corrosion. He may at once greatly reduce his scantlings for present pressures, and get rid of many difficulties of construction, or he may avail himself of the increased strength to provide for still higher pressures.

It will also be seen that these metals are equally important to the shipbuilder and to the civil engineer. This is strongly brought out in considering the immense advantages to be derived from their use in large structures. Think for a moment of this in connection with the erection of the Forth bridge or of the Eiffel tower. If the engineers of those stupendous structures had had at their disposal a metal of 40 tons strength and 28 tons elastic limit, instead of 30 tons strength and 17 tons elastic limit in the one case and say 22 tons strength and 14 to 16 tons elastic limit in the other, how many difficulties would have been reduced in magnitude as the weight of materials was reduced. The Forth bridge would have become even more light and airy, and the tower more netlike and graceful than they are at present.

Then, as regards the requirements of the military engineer, I am inclined to state firmly that there have not yet been placed at his disposal materials so well adapted to his purposes—whether of armor or of armament—as those I have now brought under your notice.

In what may be called their natural condition these alloys have many properties which will commend them for these purposes, and when the best method of treatment, by hardening or tempering, has been arrived at, I believe that their qualities for armor will be unsurpassed.

In conclusion, I have to repeat what I stated in commencing, that I regret I have not been in a position to give you as much information about these alloys as I could have wished, but I have done my best in the time at my disposal and in the circumstances in which I found myself.

ALUMINUM AND ITS EXTRACTION ON A COMMERCIAL BASIS.

By F. J. SEYMOUR.

THE metal aluminum has such peculiar and desirable qualities, especially in its use as an alloy with other metals, that the writer, in the year 1878, made some practical experiments looking to its production, which consisted mainly in the attempt to separate the metal from commercial zinc, having found that the Missouri and Illinois product carried aluminum in a small percentage; and for this purpose he constructed a furnace by which the metals of greater or lesser specific gravity could be separated while in a molten state, relying upon the difference in their specific gravity, also upon the degree of heat at which each metal under treatment began to crystallize. From this period of time (the first recognition of natural affinity between the metal aluminum and zinc) would sooner or later develop the economical process for their reduction. First experiments were made under the belief that the two metals could be reached together by distillation with appliances analogous to the distillation of zinc ores, and that the two ores, by treating together with carbon and other fluxes, could be cast down as an alloy in a metallic condition. Partial success was reached in these experiments, but it became apparent that the conditions for successful treatment should include an arrangement so complete that the very ethereal vapors distilled from the ores must be held under more rigid conditions than were needed for the distillation of zinc ores alone; and after repeated careful experiment on a practical basis, he finally determined that the economical process for obtaining the metal aluminum would be found by a process of vaporization and condensation, and under such condition as would hold under proper control the vapors liberated and almost entirely excluded from contact with the atmosphere; also subject to such conditions as would allow the introduction of hydrocarbon and other gases at any time needed to make perfect reduction and concentration of the silica and impurities, thereby making such concentration as would deliver the mineral contained in the ores in the condition of their oxides at one point, and the impurities to be delivered at another, and to be done by such an arrangement of appliances as would include cheap labor and the handling of large numbers of furnaces and large quantities of material.

Early effort to obtain this metal may be said to have commenced about the year 1855, since which time Messrs. Bell & Co., Wurtz & Co., De Ville, Wohler, and later James Webster and Freishmuth, of our own country, have each made success in obtaining the metal, but at such cost as to exclude its use for common purposes, and thereby it has been out of reach for those purposes for which its inherent qualities render the metal peculiarly adapted.

My process for obtaining aluminum is substantially as follows, and consists in taking the natural earths carrying the metal and treating them with calamine or carbonate zinc ore and other fluxes.

The formula is substantially as follows: Carbonate zinc ore 100 parts, kaolin 100 parts, carbon, either as anthracite coal or its equivalent in hydrocarbon gas, 125 parts, pearlash or its equivalent 15 parts, chloride sodium or its equivalent 10 parts, and may be varied somewhat, all these parts (except hydrocarbon gas when used) to be intimately mixed together by grinding under heavy rollers.

It has been found that the earths or ores peculiar to America carrying aluminum are mainly composed of silica and alumina in about equal proportion, viz., an average 40 per cent. alumina and 45 per cent. silica, the balance of parts being moisture and impurities. The union of the alumina and silica as found in the natural earths is to a certain extent a mechanical, not a chemical one, and it has also been found that all attempts to cast down the metal from the natural earths directly or by any process analogous to the general method of metallurgic operation, or to the method generally in use for the distillation of zinc ores, have failed, for the reason that alumina in its natural condition, as found in the various earths, is so very highly sublimated, also is so very light in its specific gravity when reduced into a metallic condition, that all the common methods of treating it by heat, either in an open crucible or by distillation, will fail to cast it down in any way analogous to the common methods of treating ores.

The method herein described consists mainly in the use of zinc ore of the calamine or carbonate order, with kaolin or earths carrying alumina, for the reason that the one metal has such chemical affinity for the other, and the one such greater gravity than the other, that when mixed in proper proportions and subjected to heat under conditions as hereinafter explained, the one will act as a flux and assist in liberating the oxides to be taken down together, either as the oxides of the two metals, or in a metallic condition.

The deposit of alumina in all the rocks and earths is found in such sublimated condition as to approach more closely than most other deposits of mineral to what may be stated as nearer the density of the atmosphere, and under a moderate degree of heat is expelled in such rarefied vapor as to escape observation.

A quantity of kaolin placed under heat in open crucible (showing 40 per cent. alumina by critical analysis) will vaporize before the silica is calcined and reduced, and will have entirely disappeared, so that no trace is found by the same analysis as the one preceding its being placed under heat.

Many inquiries have been made to determine from what source the great deposit of alumina is projected. Geologists determine that one-eighth per cent. of the entire crust of the earth is an aluminous deposit. There are certain localities and special formations of the earth's surface that show in excess the deposit of this mineral, notably the drift clays in America. The valley of the Connecticut river shows a drift clay of ancient origin, yet the deposit is still progressing, resulting mainly from the abrasion of granite and feldspar rocks carried down by the current and left as sediment, accumulating since the early history of this notable river.

Extensive deposits of kaolin are found in the State of Georgia almost white and free from iron. This kaolin will show 40 per cent. aluminum, 47 per cent. silica, the balance moisture and impurities.

An immense deposit of kaolin clay is found in Virginia, carrying 60 per cent. aluminum and 9 per cent. silica, the balance moisture and impurities, with a trace of iron.

An abundant supply of clay adapted for the purposes of treatment by this process is found in the State of New York, notably in the vicinity of Syracuse. Large deposits are also found in some of the Western States and Territories, notably Colorado. Generally the kaolin of all the deposits mentioned, except that noticed in Virginia, shows about equal proportions of aluminum and silica.

The process herein described proposes to treat kaolin in its natural condition direct by heat, and includes making use of such fluxes as may be used to advantage in its reduction and concentration, and delivering it in the condition of oxide, and by subsequent treatment into an alloy of the two metals.

A furnace proper for this work may be described as follows, and would include capacity for reducing two tons of the ore of alumina and zinc in twenty-four hours. The use of fuel in form of gas is very desirable, as it may be obtained of such purity as to be driven directly upon the ores without crucibles. Its use as fuel also enables making the process continuous, and the necessity of stopping for cleaning and gathering the product a question of days, at the option of the operator.

The furnace for the reduction of ores may also be so constructed as to admit of crucible work to be used in the reduction of the oxide into metal alone, and the production of alloys of aluminum with all the metals for which it has any affinity.

The burners used in this furnace are constructed upon the blowpipe principle. Each burner has six pipes for gas and thirteen pipes for air. The gas is delivered through the burner and into the furnace under a pressure of one and a half pounds; the air is delivered through the burner and into the furnace under about the same pressure; the gas and air first come into contact at the point where combustion first takes place. The force by which each is impelled carries the consuming gas and heat directly upon the ores under treatment. Both gas and air have their independent chamber and valve, and the proportions of each, as delivered into the furnace, is such as to make combustion perfect, and both under complete control of the operator. The result of this arrangement includes an intense heat exactly upon the points in the furnace desirable to reach. The reduction chamber of this furnace may be fourteen inches square and fifteen feet long, provided at its ends with adjustable openings for the purpose of raking out the debris after the mineral has been expelled; also, provided at intervals, extending along its entire length, at its side surface, with openings to admit the projection of the pipes or burners to the proper distance under the outer wall of the furnace. Each burner having its independent supply of gas and air, and once adjusted, will run continuously for an indefinite length of time without changing the degree of heat attained in the furnace chamber.

This furnace is also provided at its upper side or floor with openings, at intervals, for the admission of crucibles or ores for concentration; and, also, with appliances for lifting crucibles from the reduction chamber, when desired. Each of the openings, as before described, communicates directly with the reduction chamber, and is each provided with a separate flue, and all communicate with a common heating chamber lying above and parallel, and is a part of furnace construction, as described above. This heating chamber is 30 inches wide, 36 inches high, and 15 feet long, constructed so thoroughly as to be able to sustain as great heat as the reduction chamber below, and may be designated chamber No. 1.

The mineral vapors expelled from the ores are carried by the blast and natural draught into this heating chamber, and there become homogeneous and uniformly sublimated. This is desirable, as the ores are fed into the reduction chamber below at somewhat irregular intervals. This heating chamber is provided at the top and center with a single outlet which communicates, by means of a flue, with a brick chamber, No. 2, 15 feet in diameter and 8½ feet high. The result to be secured by this chamber is a reduction of the heat and mineral vapors; also allows the vapors carrying the oxides of the minerals to become more homogeneous and better fitted for treatment by the reagents for precipitation, which is to follow. This chamber is provided with outlets at intervals through its arched top, which becomes the floor of the chamber to which it communicates.

Chamber No. 3 is of brick and thoroughly built; is 15 feet diameter, 10½ feet high, and cone shaped. The heat and vapors coming from the chamber below, through the arched floor, are met in this chamber by a spray of a weak solution of carb. potash, forced into a spray by a pressure of the atmosphere driven by a pressure blower. This chamber is also provided at its extreme upper end with an outlet through which projects a pipe, which may serve two purposes, one for carrying the hydrates of ammonia into and among the heat and vapor with which it is constantly being supplied, and the other as a measure of safety in determining the pressure carried. This is done by means of a pressure gauge attached to the lower end of the pipe or outlet.

This cone-shaped chamber, No. 3, is provided with an outlet pipe, somewhat below the center of its altitude, 20 inches in diameter, and communicates with a series of copper cylinders 6 feet in diameter and 5 feet long. These copper cylinders are placed at intervals of about six feet, the one from the other, and communication with each made by a continuation of the 20 inch pipe. This pipe extends beyond the copper cylinders and into a chimney for the escape of sulphurous material, if desired. The outlet pipe near the chimney is provided with a damper, or means for shutting off or checking the escape of any material that would be desirable to save, thus enabling the product continually liberated from the reduction furnace to be treated throughout the system on the retort or distillation principle. The copper cylinders or condensers are each provided, at their extreme upper diameter, with inlet pipes, which project inside the cylinders, to which are attached a bulb or sprayer, for the purpose of filling the inside of the cylinders with water in a mist or spray carrying a reagent in order to make complete the precipitation of the mineral vapors coming from the reduction furnace.

This system of reduction and appliances enables the operator to bring the heat and sublimated oxides liberated from the ores by the reduction furnace through a series of cooling and condensing chambers, and then down to nearly the normal temperature of the atmosphere, which includes the opportunity to have made complete precipitation of the mineral contained in the ores under treatment. The copper condensing cylinders are also provided, at the extreme point of their lower diameter, with outlet pipes through which are carried automatically the flow of water and condensed mineral down and into vaporizing and drying pans. These pans are 24 feet long, 5 feet wide, and 5 inches deep. The flow of water or fluid coming from the condensing cylinders is directly over and in contact with heat, and at such degree as will vaporize the water from the mineral coming from the condensing cylinders and chambers about as rapidly as will keep the vaporizing pans from overflow. This enables the operator to make his runs of the furnace of such length as to result in economy in gathering the mineral, and all from the reducing chamber through to the product of dry oxide, and may be made rapid or slow, according to the degree of heat applied at the reduction furnace, including the amount of cooling material and reagents through which the liberated mineral vapors are obliged to come into contact in their transmission through the various stages of cooling and precipitating. This process will deliver the oxides nearly chemically pure, and in such condition as to be readily absorbed by metals in a molten state, notably iron, steel, copper, tin, and zinc, making an alloy with these metals, and increasing greatly their good qualities.

This product of alloys, including aluminum, bronze, nickel and tin alloys, aluminized iron and steel, is crucible work, and may be done in what is here described as the reduction furnace, and as follows. The metal to be alloyed is first placed in the crucible and under heat, and after being brought to a melted condition of ebullition, the fluxes, which include the oxides, are added, and then the crucible covered, and should be subjected to high heat for forty-five minutes, or until the fluxes have been almost disintegrated and absorbed by heat. Copper and nickel alloys with aluminum are greatly improved in quality by being recast, and do not lose their durable qualities by this being repeated many times. The reduction of the oxides aluminum and zinc into their alloys consists in packing a quantity of the oxides in crucibles, first having been thoroughly and intimately mixed with carbon and proper fluxes, and subjecting to a proper degree of heat. The character of the treatment of the two ores has led them into such intimate and such close relationship that under heat as above a considerable portion of the metals contained in the oxide is liberated, and the heavy metal will carry the lighter down into an alloy, and the percentage of each will correspond nearly to the percentage of each ore submitted for treatment in the reduction furnace.

The separation of the aluminum from the zinc, as found in the alloys obtained as described above, may be accomplished by two methods. One by heat and nearly complete volatilization of the zinc, leaving the aluminum behind. Metallic zinc volatilizes easily and is easily expelled from the alloy. Aluminum does not volatilize easily after once in a metallic condition. This may be done and separations made under conditions in which the vaporized zinc may be saved.

Another method is accomplished by the difference in their specific gravity, which under moderate heat, and separating by agitation, the lighter metal may be taken from the surface almost chemically pure, and the heavier metal from the bottom. It is desirable that by this process of separation the volume of metal under treatment should be of such quantity that fresh alloy may be added from time to time without changing materially the temperature of the volume under heat, thereby making the process continuous and the two metals zinc and aluminum obtained in commercial form and useful for any purpose for which the two metals may be adapted.

ALUMINUM.*

By Sir HENRY ROSCOE, M.P., D.C.L., LL.D., V.P.R.S.

CHEMISTS of many lands have contributed to our knowledge of the metal aluminum. Davy, in 1807, tried in vain to reduce alumina by means of the electric current. Oerstedt, the Dane, in 1824 pointed out that the metal could be obtained by treating the chloride with an alkali metal; this was accomplished in Germany by Wohler in 1827, and more completely in 1845, while in 1854, Bunsen showed how the metal can be obtained by electrolysis. But it is to France, by the hands of Henri Ste.-Claire Deville, in the same year, that the honor belongs of having first prepared aluminum in a state of purity and of obtaining it on a scale which enables its valuable properties to be recognized and made available, and the bar of "silver-white metal from clay" was one of the chemical wonders in the first Paris exhibition of 1855. Now England and America step in, and I have this evening to relate the important changes which further investigation has effected in the metallurgy of aluminum. The process suggested by Oerstedt, carried out by Wohler, and modified by Deville, remains in principle unchanged. The metal is prepared, as before, by a reduction of the double chloride of aluminum and sodium, by means of metallic sodium in presence of cryolite; and it is therefore not so much a description of a new reaction as of improvements of old ones of which I have to speak.

I may perhaps be allowed to remind my hearers that more than 33 years ago, Mr. Barlow, then secretary to the Institution, delivered a discourse in the presence of M. Deville on the properties and mode of preparation of aluminum, then a novelty. He stated that the metal was then sold at the rate of £3 per ounce, and the exhibition of a small ingot, cast in the laboratory by M. Deville, was considered remarkable. As indicating the progress since made, I may remark that the metal is now sold at 20s. per lb., and manufactured by the ton, by the Aluminum Company, at their works at Oldbury, near Birmingham. The improvements which have been made in this manufacture by the zeal and energy of Mr. Castner, an American metallurgist, are of so important a character that the process may properly be termed the Deville-Castner process.

The production of aluminum previous to 1887 prob-

* A lecture delivered at the Royal Institution of Great Britain, May 3, 1889.—*Chem. News.*

ably did not exceed 10,000 lb. per annum, while the price at that time was very high. To attain even this production required that at least 100,000 lb. of double chloride and 40,000 lb. of sodium should be manufactured annually. From these figures an idea of the magnitude of the undertaking assumed by the Aluminum Company may be estimated, when we learn that they erected works having an annual producing capacity of 100,000 lb. of aluminum. To accomplish this required not only that at least 400,000 lb. of sodium, 800,000 lb. of chlorine, and 1,000,000 lb. of double chloride should be annually manufactured, but in addition that each of these materials should be produced at a very low cost, in order to enable the metal to be sold at 20s. per lb.

The works now cover a space of nearly five acres. They are divided into five separate departments, viz., 1st, sodium; 2d, chlorine; 3d, chloride; 4th, aluminum; and 5th, foundry, rolling, wire mills, etc.

In each department an accurate account is kept of the production each day, the amount of material used, the different furnaces and apparatus in operation, etc. In this manner it has been found possible to ascertain each day exactly how the different processes are progressing, and what effect any modification has, either on cost, quantity, or quality of product. By this means a complicated chemical process is reduced to a series of very simple operations, so that while the processes are apparently complicated and difficult to carry out successfully, this is not the case now that the details connected with the manufacture have been perfected, and each operation carried on quite independently until the final materials are brought together for the production of the aluminum.

MANUFACTURE OF SODIUM.

The first improvement occurs in the manufacture of sodium by what is known as the "Castner process." The successful working of this process marks an era in the production of sodium, as it not only has greatly cheapened the metal, but has enabled the manufacture to be carried out upon a very large scale with little or no danger. Practically, the process consists in heating fused caustic soda in contact with carbon while the former substance is in a perfectly liquid condition. By the process in vogue before the introduction of this method, it was always deemed necessary that special means should be taken to guard against actual fusion of the mixed charges, which, if it were to take place, would to a large extent allow the alkali and reducing material to separate. Thus, having an infusible charge to heat, requiring the employment of a very high temperature for its decomposition, the iron vessels must be of small circumference to allow the penetration of the heat to the center of the charge without actually melting the vessel in which the materials are heated. By the new process, owing to the alkali being in a fused or perfectly liquid condition in contact directly with carbon, the necessity of this is avoided, and consequently, the reduction can be carried on in large vessels at a comparatively low temperature. The reaction taking place may be expressed as follows:

$$3NaHO+C=Na_2CO_3+3H+Na.$$

The vessels in which the charges of alkali and reducing material are heated are of egg-shaped pattern, about 18 inches in width at their widest part and about 3 feet high, and are made in two portions, the lower one being actually in the form of a crucible, while the upper one is provided with an upright stem and a protruding hollow arm. This part of the apparatus is known as the cover. In commencing the operation, these covers are raised in the heated furnace through apertures provided in the floor of the heated chamber, and are then fastened in their place by an attachment adjusted to the stem; the hollow arm extends outside the furnace. Directly below each aperture in the bottom of the furnace are situated the hydraulic lifts, attached to the top of which are the platforms upon which are placed the crucibles to be raised into the furnace. Attached to the hydraulic lifts are the usual reversing valves for lowering or raising, and the platform is of such a size as, when raised, completely to fill the bottom aperture of the furnace. The charged crucible, being placed upon the platform, is raised into its position, the edges meeting those of the cover, forming an air-tight joint which prevents the escape of gas and vapor from the vessel during reduction, except by the hollow arm provided for this purpose. The natural expansion of the iron vessels is accommodated by the water pressure in the hydraulic lifts, so that the joint of the cover and crucible are not disturbed until it is intended to lower the lift for the purpose of removing the crucible.

The length of time required for the first operation of reduction and distillation is about two hours. At the end of this time the crucibles are lowered, taken from the platforms by a large pair of tongs on wheels, carried to a dumping pit, and thrown on their side. The residue is cleaned out, and the hot pot, being again gripped by the tongs, is taken back to the furnace. On its way, the charge of alkali and reducing material is thrown in. It is again placed on the lift and raised in position against the edges of the cover. The time consumed in making the change is one and a half minutes, and it only requires about seven minutes to draw, empty, recharge, and replace the five crucibles in each furnace. In this manner the crucibles retain the greater amount of their heat, so that the operation of reduction and distillation now only requires one hour and ten minutes. Each of the four furnaces, of five crucibles each, when in operation, is drawn alternately, so that the process is carried on night and day.

Attached to the protruding hollow arm from the cover are the condensers, which are of a peculiar pattern specially adapted to this process, being quite different from those formerly used. They are about 5 inches in diameter, and nearly 3 feet long, and have a small opening in the bottom about 20 inches from the nozzle. The bottom of these condensers is so inclined that the metal condensed from the vapor issuing from the crucible during reduction flows down and out into a small pot placed directly below this opening. The uncondensed gases escape from the condenser at the further end, and burn with the characteristic sodium flame. The condensers are also provided with a small hinged door at the further end, by means of which the workmen from time to time may look in to observe how the distillation is progressing. Previous to drawing the crucibles from the furnace for the purpose of emptying and recharging, the small pots each containing the distilled metal are removed, and empty ones substituted. Those removed each contain on an average about 6 lb. of metal, and are taken directly to the sodium casting shop, where it is melted and cast, either into large bars ready to be used for making aluminum, or in smaller sticks to be sold.

Special care is taken to keep the temperature of the furnaces at about 1,000° C., and the gas and air valves are carefully regulated, so as to maintain as even a temperature as possible. The covers remain in the furnace from Sunday night to Saturday afternoon, and the crucibles are kept in use until they are worn out, when new ones are substituted without interrupting the general running of the furnace. A furnace in operation requires 250 lb. of caustic soda every one hour and ten minutes, and yields in the same time 30 lb. of sodium and about 240 lb. of crude carbonate of soda. With the four furnaces at work 120 lb. of sodium can be made every seventy minutes, or over a ton in the twenty-four hours. The residual carbonate, on treatment with lime in the usual manner, yields two-thirds of the original amount of caustic operated upon. The sodium, after being cast, is saturated with kerosene oil, and stored in large tanks holding several tons, placed in rooms specially designed both for security against either fire or water.

CHLORINE MANUFACTURE.

This part of the works is connected with the adjacent works of Messrs. Chance Bros. by a large gutta percha pipe, by means of which from time to time hydrochloric acid is supplied direct into the large storage cisterns, from which it is used as desired for making the chlorine. For the preparation of the chlorine gas needed in making the chloride, the usual method is employed; that is, hydrochloric acid and manganese dioxide are heated together, when chlorine gas is evolved with effervescence, and is led away by earthenware and lead pipes to large lead-lined gasometers, where it is stored.

The materials for the generation of the chlorine are brought together in large tanks, or stills, built up out of great sandstone slabs, having rubber joints, and the heating is effected by the injection of steam. The evolution of gas, at first rapid, becomes gradually slower, and at last stops; the hydrochloric acid and manganese dioxide being converted into chlorine and manganous chloride. This last compound remains dissolved in the "spent still liquor," and is reconverted into manganese dioxide, to be used over again, by Weldon's manganese recovery process. Owing to the difficulty of keeping up a regular supply of chlorine under a constant pressure directly from the stills, in order that the quantity passed into the sixty different retorts in which the double chloride is made can be regulated and fed as desired, four large gasometers were erected. Each of these is capable of holding 1,000 cubic feet of gas, and is completely lined with lead, as are all the connecting mains, etc., this being the only available metal which withstands the corrosive action of chlorine. The gasometers are filled in turn from the stills, the chlorine consumed being taken direct from a gasometer under a regular pressure until it is exhausted; the valves being changed, the supply is taken from another holder, the emptied one being refilled from the still.

MANUFACTURE OF THE DOUBLE CHLORIDE.

Twelve large regenerative gas furnaces are used for heating, and in each of these are fixed five horizontal fire clay retorts about 10 feet in length, into which the mixture for making the double chloride is placed. These furnaces have been built in two rows, six on a side, the clear passageway down the center of the building, which is about 250 feet long, being 50 feet in width. Above this central passage is the staging, carrying the large lead mains for the supply of the chlorine coming from the gasometers. Opposite each retort and attached to the main are situated the regulating valves, connected with lead and earthenware pipes, for the regulation and passage of the chlorine to each retort. The valves are of peculiar design, and have been so constructed that the chlorine is made to pass through a certain depth of liquid, which not only, by opposing a certain pressure, allows a known quantity of gas to pass in a given time, but also prevents any return from the retort into the main, should an increase of pressure be suddenly developed in the retorts.

The mixture with which the retorts are charged is made by grinding together hydrate of alumina, salt, and charcoal. This mixture is then moistened with water, which partially dissolves the salt, and thrown into a pug mill of the usual type for making drain pipes, excepting that the mass is forced out into solid cylindrical lengths upon a platform alongside of which a workman is stationed with a large knife, by means of which the material is cut into lengths of about three inches each. These are then piled on top of the large furnaces to dry. In a few hours they have sufficiently hardened to allow of their being handled. They are then transferred to large wagons, and are ready to be used in charging the retorts.

The success of this process is in a great measure dependent, 1st, on the proportionate mixture of materials; 2d, on the temperature of the furnace; 3d, on the quantity of chlorine introduced in a given time, and 4th, on the actual construction of the retorts. I am, however, not at liberty to discuss the details of this part of the process, which have only a commercial interest. In carrying on the operation the furnaces or retorts, when at the proper temperature, are charged by throwing in the balls until they are quite full, the fronts are then sealed up, and the charge allowed to remain undisturbed for about four hours, during which time the water of the alumina hydrate is completely expelled. At the end of this time the valves on the chlorine main are opened, and the gas is allowed to pass into the charged retorts. In the rear of each retort, and connected therewith by means of an earthenware pipe, are the condenser boxes, which are built in brick. These boxes are provided with openings or doors, and also with earthenware pipes, connected with a small flue for carrying off the uncondensed vapors to the large chimney. At first the chlorine passed into each retort is all absorbed by the charge, and only carbonic oxide escapes into the open boxes, where it burns. After a certain time, however, dense fumes are evolved, and the boxes are then closed, while the connecting pipe between the box and the small flue serves to carry off the uncondensed vapors to the chimney.

The reaction which takes place is as follows:

$$Al_2O_3+2NaCl+3C+6Cl=2AlCl_3NaCl+3CO.$$

The chlorine is passed in for about seventy-two hours in varying quantity, the boxes at the back being opened from time to time by the workmen to ascertain the progress of the distillation. At the end of the time mentioned the chlorine valves are closed and the boxes at the back of the furnace are all thrown open. The crude double chloride, as distilled from the retorts, condenses in the connecting pipe and trickles down into the boxes, where it solidifies in large irregular masses. The yield from a bench of five retorts will average from 1,600 to 1,800 lb., which is not far from the theoretical quantity. After the removal of the crude chloride from the condenser boxes the retorts are opened at their charging end, and the residue, which consists of a small quantity of alumina, charcoal, and salt, is raked out and remixed in certain proportions with fresh material to be used over again. The furnace is immediately recharged and the same operations repeated, so that from each furnace upward of 3,500 lb. of chloride are obtained weekly. With ten of the twelve furnaces always at work the plant is easily capable of producing 30,000 lb. of chloride per week, or 1,500,000 lb. per annum.

Owing to the presence of iron, both in the materials used (viz., charcoal, alumina, etc.) and in the fire clay composing the retorts, the distilled chloride always contains a varying proportion of this metal in the form of ferrous and ferric chlorides. When it is remembered that it requires 10 lb. of this chloride to produce 1 lb. of aluminum by reduction, it will be quite apparent how materially a very small percentage of iron in the chloride will influence the quality of the resulting metal. I may say that, exercising the utmost care as to the purity of the alumina and the charcoal used, and after having the retorts made of special fire clay containing only a very small percentage of iron, it was found almost impossible to produce upon a large scale a chloride containing less than 0·3 per cent. of iron.

This crude double chloride, as it is now called at the works, is highly deliquescent, and varies in color from a light yellow to a dark red. The variation in color is not so much due to the varying percentage of iron contained as to the relative proportion of ferric or ferrous chlorides present, and although a sample may be either very dark or quite light, it may still contain only a small percentage of iron if it be present as ferric salt, or a very large percentage if it is in the ferrous condition.

Even when exercising all possible precautions, the average analysis of the crude double chloride shows about 0·4 per cent. of iron. The metal subsequently made from this chloride, therefore, never contained much less than about 5 per cent. of iron, and, as this quantity greatly injures the capacity of aluminum for drawing into wire, rolling, etc., the metal thus obtained required to be refined. This was successfully accomplished by Mr. Castner and his able assistant Mr. Cullen, and for some time all the metal made was refined, the iron being lowered to about 2 per cent.

The process, however, was difficult to carry out, and required careful manipulation, but as it then seemed the only remedy for effectively removing the iron, it was adopted and carried on for some time quite successfully, until another invention of Mr. Castner's rendered it totally unnecessary. This consisted in purifying the double chloride before reduction.

I cannot now explain this process, but I am able to show some of the product. This purified chloride, or pure double chloride, is, as you see, quite white, and is far less deliquescent than the crude, so that it is quite reasonable to infer that this most undesirable property is greatly due to the former presence of iron chlorides. I have seen large quantities containing upward of 1½ per cent. of iron, or 150 lb. to 10,000 of the chloride, completely purified from iron in a few minutes, so that, while the substance before treatment was wholly unfit for the preparation of aluminum, owing to the presence of iron, the result was, like the sample exhibited, a mass containing only 1 lb. of iron in 10,000, or 0·01 per cent. The process is extremely simple, and adds little or no appreciable cost to the final product. After treatment, this pure chloride is melted in large iron pots and run into drums similar to those used for storing caustic soda. As far as I am aware it was generally believed to be an impossibility to remove the iron from anhydrous double chloride of aluminum and sodium, and few, if any, chemists have ever seen a pure white double chloride.

ALUMINUM MANUFACTURE.

I now come to the final stage of the process, viz., the reduction of the pure double chloride by sodium. This is effected, not in a tube of Bohemian glass, as shown in Mr. Barlow's lecture in 1856, but in a large reverberatory furnace, having an inclined hearth about six feet square, the inclination being toward the front of the furnace, through which are several openings at different heights. The pure chloride is ground together with cryolite in about the proportions of two to one, and is then carried to a staging erected above the reducing furnace. The sodium, in large slabs or blocks, is run through a machine similar to an ordinary tobacco cutting machine, where it is cut into small, thin slices; it is then also transferred to the staging above the reducing furnace.

Both materials are now thrown into a large revolving drum, when they become thoroughly mixed. The drum being opened and partially turned, the contents drop out into a car on a tramway directly below. The furnace having been raised to the desired temperature, the dampers of the furnace are all closed to prevent the access of air, the heating gas also being shut off. The car is then moved out on the roof of the furnace until it stands directly over the center of the hearth. The furnace roof is provided with large hoppers, and through these openings the charge is introduced as quickly as possible. The reaction takes place almost immediately, and the whole charge quickly liquefies. At the end of a certain time the heating gas is again introduced and the charge kept at a moderate temperature for about two hours. At the end of this period the furnace is tapped by driving a bar through the lower

opening, which has previously been stopped with a fire clay plug, and the liquid metal run out in a silver stream into moulds placed below the opening. When the metal has all been drawn off, the slag is allowed to run out into small iron wagons and removed. The openings being again plugged up, the furnace is ready for another charge. From each charge, composed of about 1,200 lb. of pure chloride, 600 lb. of cryolite, and 350 lb. of sodium, about 115 to 120 lb. of aluminum is obtained.

The purity of the metal entirely depends upon the purity of the chloride used, and without exercising more than ordinary care the metal tests usually indicate a purity of metal above 99 per cent. On the table is the metal run from a single charge, its weight is 116 lb., and its composition, as shown by analysis, is 99·2 aluminum, 0·3 silicon, and 0·5 iron. This I believe to be the largest and the purest mass of metal ever made in one operation.

The results of eight or nine charges are laid on one side, and then melted down in the furnace to make a uniform quality, the liquid metal, after a good stirring, being drawn off into moulds. These large ingots, weighing about 60 lb. each, are sent to the casting shop, there to be melted and cast into the ordinary pigs, or other shapes, as may be required for the making of tubes, sheets, or wire, or else used directly for making alloys of either copper or iron.

The following table shows approximately the quantity of each material used in the production of one ton of aluminum:

Metallic sodium	6,300 lb.
Double chloride	22,400 lb.
Cryolite	8,000 lb.
Coal	8 tons.

To produce 6,300 lb. of sodium is required:

Caustic soda	44,000 lb.
Carbide made from pitch, 12,000 lb., and iron turnings, 1,000 lb.	7,000 lb.
Crucible castings	2½ tons.
Coal	75 tons.

For the production of 22,400 lb. double chloride is required:

Common salt	8,000 lb.
Alumina hydrate	11,000 lb.
Chlorine gas	15,000 lb.
Coal	180 tons.

For the production of 15,000 lb. of chlorine gas is required:

Hydrochloric acid	180,000 lb.
Limestone dust	45,000 lb.
Lime	30,000 lb.
Loss of manganese	1,000 lb.

(These figures were rendered more evident by the aid of small blocks, each cut a given size so as to represent the relative weights of the different materials used to produce one unit of aluminum.)

It might seem, on looking over the above numbers, as if an extraordinary amount of waste occurred, and as if the production is far below that which ought to be obtained, but a study of the figures will show that this is not the case. I would wish to call attention to one item in particular, viz., fuel, it having been remarked that the consumption of coal must prevent cheap production. I think when it is remembered that coal, such as used at the works, costs only 4s. per ton, while the product is worth £2,240 per ton, the cost of coal is not an item of consequence in the cost of production. The total cost of the coal to produce one ton of metal being £50, the actual cost for fuel is less than sixpence for every pound of aluminum produced. The ratio of cost of fuel to value of product is indeed less than is the case in making either iron or steel. In concluding my remarks as to the method of manufacture and the process in general, I may add that I do not think it is too much to expect, in view of the rapid strides already made, that in the future further improvements and modifications will enable aluminum to be produced and sold even at a lower price than appears at present possible.

PROPERTIES OF ALUMINUM.

In its physical properties aluminum widely differs from all the other metals. Its color is a beautiful white, with a slight blue tint. The intensity of this color becomes more apparent when the metal has been worked, or when it contains silicon or iron. The surface may be made to take a very high polish, when the blue tint of the metal becomes manifest, or it may be treated with caustic soda and then nitric acid, which will leave the metal quite white. The extensibility or malleability of aluminum is very high, ranking with gold and silver if the metal be of good quality. It may be beaten out into thin leaf quite as easily as either gold or silver, although it requires more careful annealing.

It is extremely ductile and may be easily drawn, especial care only being required in the annealing.

The excessive sonorousness of aluminum is best shown by example (large suspended bar being struck). Faraday has remarked, after experiments conducted in his laboratory, that the sound produced by an ingot of aluminum is not simple, and one may distinguish the two sounds by turning the vibrating ingot.

After being cast it has about the hardness of pure silver, but may be sensibly hardened by hammering.

Its tensile strength varies between 12 and 14 tons to the inch (test sample which was shown having been broken at 13 tons or 27,000 lb), ordinary cast iron being about 8 tons. Comparing the strength of aluminum in relation to its weight, it is equal to steel of 38 tons tensile strength. The specific gravity of cast aluminum is 2·58, but after rolling or hammering this figure is increased to about 2·68.

The specific gravity of aluminum being 1, copper is 3·6, nickel 3·5, silver 4, lead 4·8, gold 7·7.

The fusibility of aluminum has been variously stated as being between that of zinc and silver, or between 600° and 1,000° C.

As no reliable information has ever been made public on this subject, my friend Professor Carnelley undertook to determine it. I was aware, from information gained at the works at Oldbury, that a small increase in the percentage of contained iron materially raised its point of fusion, and it has been undoubtedly due to this cause that such wide limits are given for the melting point. Under these circumstances two samples were forwarded for testing, of which No. 1, containing ½ per cent. of iron, had a melting point of 700° C.; whereas No. 2, containing 5 per cent. of iron, does not melt at 700°, and only softens somewhat above that temperature, but undergoes incipient fusion at 730°.

According to Faraday, aluminum ranks very high among metallic conductors of heat and electricity, and he found that it conducted heat better than either silver or copper. The specific heat is also very high, which accounts for length of time required for an ingot of the metal to either melt or get cold after being cast.

Chemically, its properties are well worthy of study. Air, either wet or dry, has absolutely no effect on aluminum at the ordinary temperature, but this property is only possessed by a very pure quality of metal, and the pure metal in mass undergoes only slight oxidation even at the melting power of platinum.

Thin leaf, however, when heated in a current of oxygen, burns with a brilliant bluish white light. (Experiment shown.) If the metal be pure, water has no effect on it whatever, even at a red heat. Sulphur and its compounds also are without action on it, while under the same circumstances nearly all metals would be discolored with great rapidity. (Experiment shown using silver and aluminum under the same conditions.)

Dilute sulphuric acid and nitric acid, both diluted and concentrated, have no effect on it, although it may be dissolved in either hydrochloric acid or caustic alkali. Heated in an atmosphere of chlorine it burns with a vivid light, producing aluminum chloride. (Experiment shown.) In connection with the subject it may be of interest to state the true melting point of the double chloride of aluminium and sodium, which has always been given at 170° to 180° C., but which Mr. Baker, the chemist of the works, finds lies between 125° and 130° C.

USES OF ALUMINUM.

Its uses, unalloyed, have heretofore been greatly restricted. This is, I believe, alone owing to its former high price, for no metal possessing the properties of aluminum could help coming into larger use if its cost were moderate. Much has been said as to the impossibility of soldering it being against its popular use, but I believe that this difficulty will now soon be overcome. The following are a few of the purposes to which it is at present put: Telescope tubes, marine glasses, eye glasses, and sextants, especially on account of its lightness. Fine wire for the making of lace, embroidery, etc. Leaf, in the place of silver leaf, saber sheaths, sword handles, etc., statuettes and works of art, jewelry and delicate physical apparatus, culinary utensils, harness fittings, metallic parts of soldiers' uniforms, dental purposes, surgical instruments, reflectors (it not being tarnished by the products of combustion), photographic apparatus, aeronautical and engineering purposes, and especially for the making of alloys.

ALLOYS OF ALUMINUM.

The most important alloys of aluminum are those made with copper. These alloys were first prepared by Dr. Percy, in England, and now give promise of being largely used. The alloy produced by the addition of 10 per cent. of aluminum to copper, the maximum amount that can be used to produce a satisfactory alloy, is known as aluminum bronze. Bronzes, however, are made which contain smaller amounts of aluminum, possessing in a degree the valuable properties of the ten per cent. bronze. According to the percentage of aluminum up to 10 per cent., the color varies from red gold to pale yellow. The 10 per cent. alloy takes a fine polish, and has the color of jewelers' gold. The 5 per cent. alloy is not quite so hard, the color being very similar to that of pure gold. I am indebted to Prof. Roberts-Austen for a splendid specimen of crystallized gold, as also for a mould in which the gold at the Mint is usually cast, and in this I have prepared ingots of the 10 and 5 per cent. alloy, so that a comparison may be made of the color of these with a gold ingot cast in the same mould (for the loan of which I have to thank Messrs. Johnson, Matthey & Co.), all of which are before you.

I have also ingots of the same size, of pure aluminum, from which an idea of the relative weights of gold and aluminum may be obtained.

To arrive at perfection in the making of these alloys, not only is it required that the aluminum used should be of good quality, but also that the copper must be of the very best obtainable. For this purpose only the best brands of Lake Superior copper should be used. Inferior brands of copper or any impurities in the alloy give poor results. The alloys all possess a good color, polish well, keep their color far better than all other copper alloys, are extremely malleable and ductile, can be worked either hot or cold, easily engraved, the higher grades have an elasticity exceeding steel, are easily cast into complicated objects, do not lose in remelting, and are possessed of great strength, dependent, of course, on the purity and percentage of contained aluminum. The 10 per cent. alloy, when cast, has a tensile strength of between 70,000 and 80,000 lb. per square inch, but when hammered or worked, the test exceeds 100,000 lb. (A sample shown broke at 105,000 lb.)

An attempt to enumerate either the present uses or the possible future commercial value of these alloys is beyond my present purpose. I may, however, remark that they are not only adapted to take the place of bronze, brass, and steel, but they so far surpass all of those metals, both physically and chemically, as to make their extended use assured. (Sheets, rods, tubes, wire, and ingots shown.)

But even a more important use of aluminum seems to be its employment in the iron industry, of which it promises shortly to become a valuable factor, owing to certain effects which it produces when present, even in the most minute proportions. Experiments are now being carried on at numerous iron and steel works, in England, on the Continent, and in America. The results so far attained are greatly at variance, for while in the majority of cases the improvements made have encouraged the continuance of the trials, in others the results have not been satisfactory. On this point I would wish to say to those who may contemplate making use of aluminum in this direction, that it would be advisable before trying their experiments to ascertain whether the aluminum alloy they may purchase actually contains any aluminum at all, for some of the so-called aluminum alloys contain little or no aluminum, and this may doubtless account for the negative results obtained. Again, others contain such varying proportions of carbon, silicon, and other impurities as to render their use highly objectionable.

It seems to be a prevailing idea with some people that because aluminum is so light compared with iron, they cannot be directly alloyed, and furthermore that for the same reason alloys made by the direct melting together of the two metals would not be equal to an alloy where both metals are reduced together. Now, of course, this is not the case, and the statement has been put forward by those who were only able to make the alloys in one way.

Aluminum added to molten iron and steel lowers their melting points, consequently increases the fluidity of the metal, and causes it to run easily into moulds and set there, without entrapping air and other gases, which serve to form blow holes and similar imperfections. It is already used by a large number of steel founders, and seems to render the production of sound steel castings more certain and easy than is otherwise possible.

One of the most remarkable applications of this property which aluminum possesses of lowering the melting point of iron has been made use of by Mr. Nordenfelt in the production of castings of wrought iron.

Aluminum forms alloys with most other metals, and although each possesses peculiar properties which in the future may be utilized, at present they are but little used.

In conclusion, I beg to call your attention to the wood models on the table, one being representative of aluminum, the other aluminum bronze. The originals of these models are now in the Paris exhibition, each weighing 1,000 lb. With regard to the aluminum bronze, I cannot speak positively, but the block of pure aluminum is undoubtedly the largest casting ever made in this most wonderful metal.

I have to thank the directors of the aluminum company, and especially Mr. Castner, for furnishing me with the interesting series of specimens of raw and manufactured metal for illustrating my discourse.

INDUSTRIAL APPLICATIONS OF THERMO-CHEMISTRY.

By SAMUEL RIDEAL, D.Sc., F.I.C.

THE study of the heat changes in chemical reactions during the last few years has thrown light on numerous problems of theoretical chemistry, and the labors of Julius Thomsen in Copenhagen, Berthelot in Paris, and many other investigators, have given us an accumulation of data which are now of value in several directions of applied chemistry. The fundamental principles upon which the value of thermo-chemical determinations depend are very simple. Some of the earlier work by Laplace, Lavoisier, Andrews, Favre, and Silbermann showed that the amount of heat evolved in the combination of two substances to form a new compound was equal to the amount of heat or other form of energy required to resolve the compound back into its constituents. This law, it will be seen, is in accord with the principle of the conservation of energy, and has been of value in determining the amount of work required to be done in effecting the decomposition of salts by electrolysis, and in many other directions. The second important theorem also seems to be universally true, and is in accord with the belief in the dissipation of energy. It may be called the law of maximum work, and be thus shortly stated: Every system of bodies tends to undergo that internal change that will develop the most heat. There are many familiar examples which may be cited in illustration of this principle. There are, for example, two oxides of hydrogen, water H_2O and hydrogen peroxide H_2O_2; also carbon forms the two oxides CO and CO_2. The heats of formation of these bodies from their elements have been known for some time, and they prove that the heat of formation of water is greater than that of hydrogen peroxide; but the heat of formation of carbonic acid is greater than that of carbon monoxide. Now, when hydrogen burns in air or oxygen, no hydrogen peroxide is produced, and when carbon burns no carbon monoxide is formed. Thus in these two cases the compound produced is the one which gives out the greatest amount of heat. The notation employed by chemists to denote the amount of heat change is easily understood. Thus the expression $[H_2, O] = 68{,}400$ is used to denote the heat of formation of water, and states that when 2 grammes of hydrogen are converted into water, an amount of heat equal to 68,400 gramme degrees, or sufficient to raise 68,400 grammes of water from 0° C. to 1° C., is evolved.

If we take the equation

$$H_2O + Cl_2 = 2HCl + O$$

and examine the heat changes involved in the reaction, we find that the amount of heat required to decompose a molecule of water is less than that evolved in the formation of two molecules of hydrochloric acid in solution in water. Thus

$$\begin{aligned} [H, Cl, Aq] &= 39{,}300 \\ \therefore \quad H_2O + Cl_2 &= 2HCl + O \\ 68{,}400 & \quad 78{,}600 \end{aligned}$$

There is consequently, in such a change, an evolution of about 10,000 heat units, and we should therefore expect that chlorine and water would not be a stable mixture, which is known to be the case.

In many cases, the heat of formation of a body can only be indirectly determined. For example, marsh gas (CH_4) and ethylene (C_2H_4) cannot be produced synthetically from their elements. We can determine, however, the difference in the amount of heat evolved when marsh gas (CH_4) is burnt, and a mixture of carbon and hydrogen in the same proportion. The difference between the quantities of heat evolved in these two cases—since the products are the same in each—will be the amount of heat evolved in the production of marsh gas from its elements. The apparatus required for determining accurately the quantity of heat given out in any chemical change necessarily varies with the state and kind of materials employed. Julius Thomsen uses a silver calorimeter surrounded by an outer platinum vessel containing water constantly stirred by means of a small electromotor. By turning a stopcock, the two reacting liquids are allowed to

mix, and the increase of temperature is measured by a thermometer immersed in the liquid. If the specific heat of the solution be known, and the amount of heat absorbed by the various parts of the apparatus has been determined, the total quantity of heat evolved by the reaction of known weights of the substances is then easily calculated. In experimenting with gases, Berthelot has obtained good results by means of a bomb-shaped glass vessel, into which the gases are introduced by narrow tubes, and the products of combustion caused to pass through a spiral tube surrounding the vessel. The whole apparatus is immersed in a known weight of water, from the increase of temperature of which the heat evolved in the reaction can be calculated.

Perhaps the earliest application of the principles of thermo-chemistry to the elucidation of problems outside the domain of theoretical chemistry was the determination of the e.m.f. of various forms of battery cells from the heat of combination, found by Julius Thomsen, for the salts of zinc and copper and nitric and sulphuric acids. Professor G. C. Foster, using these data, found that when 65 grammes of zinc are dissolved in a battery cell, 49,105 gramme degrees of heat are rendered available for conversion into work in a Smee's cell, 52,347 in a Daniell's element, and 90,162 in a Grove's cell. Multiplying each of these numbers by the mechanical equivalent of heat, $4{\cdot}2 \times 10^7$, and dividing by 19,010, the quantity of electricity required to electrolyze a gramme molecule, we get

$0{\cdot}886 \times 10^7$ as the e.m.f. of a Smee's cell.
$1{\cdot}156 \times 10^8$ " " Daniell's cell.
$1{\cdot}991 \times 10^8$ " " Grove's cell.

These results agree very closely with the values obtained by experiment, and would approximate still more nearly to the actual values if there were no wasteful action in the cells. More recently Nernst has studied the heat of formation of some mercury compounds, and with his data the calculated e.m.f. of various galvanic elements containing mercury as one pole is brought into agreement with the observed values.

Dieulafait also, some years ago, published a series of papers in the *Comptes Rendus* on the applications of thermo-chemistry to geological problems. The inquiry was necessarily limited to the formation of those minerals which had been produced at ordinary temperatures from substances in aqueous solution. It is obvious that, at different temperatures and under different conditions, very different amounts of heat will be evolved in the formation of the same substances, and in all applications of thermo-chemical methods this must be constantly borne in mind, or very erroneous conclusions may be arrived at. This variation in the amount of heat depends, among other things, on the change in the specific heat of the products with rise of temperature. Thus, for example, if 2 grammes of hydrogen unite with oxygen to form water at a temperature of 18° C., 68,360 heat units are evolved; while if the reaction takes place at 200° C., the heat produced is diminished to 58,230 gramme degrees. As an example of the problems which M. Dieulafait has worked out, we may take the following, which is based on the thermo-chemical data, given by him as under:

	Heat units evolved.
$2FeO + O = Fe_2O_3$	26,600
$2MnO + O_2 = 2MnO_2$	21,400
$2FeO + 2CO_2 = 2FeCO_3$	10,000
$2MnO + 2CO_2 = 2MnCO_3$	13,600

It follows from the above data, if the law of maximum work be true, that when oxygen and carbonic acid both in excess come in contact with silicates, etc., containing the oxides FeO and MnO, no carbonates will be formed; but both oxides will be converted into the higher oxides Fe_2O_3 and MnO_2. If the gases are not in excess, we should expect Fe_2O_3 and $MnCO_3$ to be produced, and no MnO_2 and $FeCO_3$. Since manganese carbonate is readily soluble, these considerations explain the formation of manganese minerals comparatively free from iron, from rocks in which iron is present in considerable quantity. Ferrous carbonate (spathic iron ore, clay iron stone) cannot be produced under these conditions, and will only be formed in a reducing medium. Among natural compounds, that which has the greatest heat of formation should constitute the principal mineral if all minerals had been deposited from aqueous solutions. The common manganese compounds, with their heats of formation, are: MnS, 23,600; MnO, 47,400; $MnCO_3$, 54,200; and MnO_2, 58,100. Of these, the latter, pyrolusite, is the one which is most abundant, while the sulphide, with the smallest heat of formation, is comparatively rare.

Thermo-chemical considerations also throw light on the association of minerals. Thus the sum of the heats of formation of zinc sulphate and calcium carbonate is greater than that of zinc carbonate and calcium sulphate, while that of zinc carbonate and magnesium sulphate is greater than that of zinc sulphate and magnesium carbonate. We should, therefore, expect to find zinc sulphate associated with limestone rocks, and zinc carbonate, or calamine, with dolomitic rocks and Epsom salt springs. It seems probable that further investigation would show that many such geological facts could be explained in a similar manner. It is well known, for example, that the magnesium silicate minerals are very stable in character, and are not acted upon by carbonic acid and water; while the alkaline and lime silicates are readily attacked. The formation of gypsum from lime rocks by sulphureted hydrogen, and its subsequent alteration, the origin of heavy spar, of sulphur in Italy, and the formation of strontianite, are all definite chemical changes, which would probably be explained if sufficient thermo-chemical data were at the disposal of the geologist.

It is, however, in the applications of the fundamental principles of thermo-chemistry to some of the chemical manufacturing processes that the most interesting and valuable results have been obtained. F. Fischer, in a recent paper on the "Utilization of Heat in Chemical Operations," has drawn attention to the fact that when a gas is given off in any chemical operation, the gas, in overcoming the atmospheric pressure, does mechanical work. It is easy to calculate the amount of heat required to liberate 1 kilog. molecule of any gas at 0° C. or any other temperature from a surface of 1 sq. m. The actual pressure of the atmosphere under ordinary conditions on 1 sq. m. is 10,366 kilog., and dividing this number by 425, the value of the mechanical equivalent of heat in meter kilogrammes, we get 24·3 as the number of heat units required to form 1 cub. m. of any gas. As the kilogramme molecule of all gases occupies 22·3 cub. m., it follows that 542 heat units are absorbed in every chemical reaction in which a kilogramme molecule of gas is evolved at 0° C. At any higher temperature, the volume of gas being greater, more work is done, and a greater quantity of heat is required. The exact figure is obtained by multiplying the number 542 by the expression $(1+0{\cdot}00366t)$ where t is the temperature of the gas. The heat which is absorbed in this way by a gas as it is formed is evolved again as soon as the gas is absorbed by a liquid, as is the case in the oxidation of Weldon mud or the manufacture of bleaching powder. The total amount of heat produced in burning one unit weight of coal must be divided into available heat, and the quantity required by the formation of the gaseous products at the temperature of the furnace. The amount of heat required to accomplish this work is, as a rule, very small, compared with the total amount of heat evolved in a chemical change, and may, in most cases, be disregarded.

Thermo-chemistry has been applied to several of the methods used or proposed in the alkali industry by Fischer, Pourcel, and others. Thus the source of all free chlorine or hydrochloric acid must be one of the common chlorides, viz., sodium chloride, magnesium chloride, or calcium chloride. The heats of formation of these bodies are, according to Thomsen:

$[Na_2, Cl_2] = 195{,}380$
$[Mg, Cl_2] = 151{,}010$
$[Ca, Cl_2] = 169{,}820$

From these chlorides, chlorine can be obtained by electrolysis, and these numbers give approximately the amount of energy required to effect their decomposition, assuming that the liberated metal remains free. Chlorine can also theoretically be obtained from all chlorides by the action of oxygen thus

$$M''Cl_2 + O = M''O + Cl_2,$$

and hydrochloric acid by the action of steam,

$$M''Cl_2 + H_2O = M''O + 2HCl, \text{ or}$$
$$M'Cl = H_2O = MHO + HCl.$$

If we examine these equations thermo-chemically in each special case, we require, in addition to the heats of formation of the chlorides, the following thermo-chemical data:

$[Na_2, O]$	= 80,400	$[Mg, O]$	= 144,000
$[Ca, O]$	= 130,900	$[Na, O, H, Aq]$	= 101,900
$[H, Cl]$	= 22,000	$[H_2, O]$	= 68,360
$[H_2, O]$ as steam = 57,000.			

Applying these data, we get the following series of equations:

	Heat required.
(1) $2NaCl + O = Na_2O + Cl_2$ $-195{,}380 \quad +80{,}400$	151,000
(2) $MgCl_2 + O = MgO + Cl_2$ $-151{,}000 \quad +144{,}000$	7,000
(3) $CaCl_2 + O = CaO + Cl_2$ $-169{,}820 \quad +130{,}900$	39,000

It will be seen that, in order to decompose sodium chloride by oxygen, an enormous amount of heat would be required, while the decomposition of magnesium chloride by ignition in a current of air requires comparatively only a small amount of heat, and is, from a thermo-chemical point of view, the most feasible of the three methods. As far back as 1870, Larkin and White obtained provisional protection for obtaining chlorine by the reaction of oxygen upon metallic chlorides at a high temperature, and various attempts have since been made to manufacture chlorine in this manner. In the simple equation

$$\underset{44{,}000}{2HCl} + O = \underset{57{,}000}{H_2O} + Cl_2$$

the reaction is one which evolves 13,000 heat units, and will take place when started without the further addition of heat, if the apparatus be properly constructed to prevent loss of heat by radiation. In the Deacon and Kingzett process, this change is effected, and Kingzett has also shown that the decomposition of dry magnesium chloride by air takes place in a heated tube. Mond's experiments with nickel oxide and ammonium chloride are also reactions which belong to this class; but the thermo-chemical data are not available for fully studying the changes which occur. In the Weldon-Pechiney process, a mixture of chlorine and hydrochloric acid is obtained by heating the hydrated magnesium oxychloride in a current of air at 1,000° C. In the three equations

	Heat units required.
$2NaCl + H_2O = Na_2O + 2HCl$ $-195{,}380 - 57{,}000 \quad +80{,}400 + 44{,}000$	128,000
$MgCl_2 + H_2O = MgO + 2HCl$ $-151{,}000 - 57{,}000 \quad +144{,}000 + 44{,}000$	20,000
$CaCl_2 + H_2O = CaO + 2HCl$ $-169{,}820 - 57{,}000 \quad +130{,}900 + 44{,}000$	52,000

we see that less heat is required to form hydrochloric acid from magnesium chloride by the action of steam than from sodium or calcium chloride. The Weldon-Pechiney process then would not seem to be applicable to the decomposition of any of these other chlorides without the expenditure of a large amount of heat, and magnesium chloride is a far more suitable material for the generation of chlorine or hydrochloric acid than calcium chloride. It will be seen, therefore, that in the Weldon-Pechiney process 7,000 heat units are required to form 71 kilog. of chlorine gas, and 20,000 units to form 73 kilog. of hydrochloric acid. Fischer has calculated the amount of heat required in raising the materials to the temperature of the reaction, which has to be added to the heat required to do the chemical work in the process. Assuming that 36·5 kilog. of hydrochloric acid are evolved to every 35·5 kilog. of chlorine, he finds that 36 kilog. of steam and 8 kilog. of oxygen supplied in the shape of 200 cub. m. of air will be required. Knowing the specific heats of all the materials, no less than 135,000 heat units are required to obtain all these bodies at 1,000° C., and of these 62,000 units are utilized in raising the temperature of the 200 cub. m. of air. The total amount of heat consumed is still further increased by the loss of heat by radiation of the brick work.

Pourcel has also used Berthelot's numbers for showing the amount of heat required in the ammonia soda process, and has pointed out the advantages to be derived from using magnesia in the place of lime for decomposing the ammonium chloride produced.

In the Leblanc process for making salt cake, it is well known that the evolution of hydrochloric acid takes place in two stages, represented by the equations

(1) $NaCl + H_2SO_4 = NaHSO_4 + HCl$
(2) $NaCl + NaHSO_4 = Na_2SO_4 + HCl$

and that the second of these reactions requires a considerable amount of heat; while, for the former, scarcely any heat is required.

Thermo-chemistry affords an explanation of these facts, as will be seen from the data given by Fischer:

	Heat required.
$NaCl + H_2SO_4 = NaHSO_4 + HCl$ $-97{,}700 - 193{,}000 + 267{,}800 + 22{,}000 =$	500
$2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl$ $-195{,}400 - 193{,}000 + 328{,}500 + 44{,}000 =$	15,800

The number of heat units—15,800—required to do the chemical work represented by the last equation is considerably short of the total heat required to effect the change in a salt cake furnace. We have seen already that heat is required for the mechanical work done by the gaseous hydrochloric acid in overcoming atmospheric pressure, and in addition heat is used in heating the sodium sulphate produced, as well as the water which takes place in the reaction. As the hydrochloric acid is evolved at a temperature of about 400°, some heat is also carried away by it. Fischer has calculated that the total quantity of heat utilized in a sulphate furnace in this way is about 66,000 units; while, on condensing the hydrochloric acid and steam in water, about 45,000 units are removed by cooling. The actual amount of heat utilized in effecting the purely chemical part of the process is, therefore only about a quarter of the amount of heat consumed.

Other interesting results are obtained in applying thermo-chemical data to the chemical changes involved in the recovery of manganese in the Weldon recovery process. It is well known that the formation of Weldon mud by oxidation with air sets heat free, so that the change, when once started, takes place without the application of any additional heat. If we compare the heats of formation of $[Mn, O, H_2O] = 94{,}770$ and $[Mn, O_2, H_2O] = 116{,}330$, we see that this is what might be expected. In liberating chlorine by the action of hydrochloric acid upon this compound, no heat is necessary, as will be seen from the equation

$$MnO_2OH_2 + 4HClAq = MnCl_2Aq + Cl_2 + 3H_2O$$
$$-116{,}300 - 148{,}000 + 128{,}000 + 205{,}200 = +68{,}900.$$

In this last equation, it is assumed by Fischer that the body written $MnO_2{\cdot}OH_2$ is a definite compound, and that in the decomposition by hydrochloric acid the third molecule of water is produced from the hydrogen and oxygen in the compound.

To take one other illustration from the alkali industry, we know that in the manufacture of a chlorate, merely warming the solution of hypochlorite first produced is sufficient to complete the change. If we examine the equation

$$3KClOAq = KClO_3Aq + 2KClAq$$
$$-3 \times 88{,}000 + 85{,}800 + 202{,}000 = +23{,}800$$

we notice that heat is evolved in the change, and therefore we should expect the hypochlorite to be unstable and readily transformed into a mixture of chlorate and chloride.

In a recent paper communicated to the Iron and Steel Institute, Mr. Pourcel has endeavored to apply the data of thermal chemistry to metallurgical reactions. Unfortunately for readers of this paper, the author has adopted Berthelot's data, calculated on the old system of atomic weights; and although the conclusions will be true, whatever system of notation be employed, yet it would have been better for modern readers to have had the formulæ of the reacting substances giving in the usually accepted form. In this part of his paper he first refers to the conclusions which MM. Troost and Hautefeuille arrived at from their experiments on the heats of formation of the compounds of iron and manganese with carbon, silicon, phosphorus, and sulphur. Their experiments prove that the iron carbides are formed with absorption of heat, and that consequently they are unstable bodies, so that on cooling, pig iron parts with its carbon and disengages a certain quantity of heat. By rapid cooling this dissociation of the unstable iron carbide is prevented, and white pig iron is produced. On the other hand, their investigation has shown that manganese carbide is produced with evolution of much heat, and is therefore a very stable body. It is therefore highly probable that the manganese present in pig iron and steel exists there as a carbide. In the Bessemer converter this compound resists decomposition for a longer time than the other bodies present in the pig iron employed. In their examination of the compounds of silicon with iron and manganese, they noticed a similar difference. The iron silicides are unstable, being produced with absorption of heat, and will therefore be readily oxidized to silica and metallic iron in the Bessemer converter. The manganese silicides, on the other hand, are stable compounds, and are produced with evolution of heat, but less than that of the manganese carbide.

In the Bessemer process, then, the oxidation of the materials takes place in the following order: (1) Iron silicide; (2) manganese silicide; (3) manganese carbide. Phosphorus forms stable compounds with both iron and manganese, and hence the difficulty of removing this element from pig iron. With sulphur the compound MnS is formed with the evolution of about twice the amount of heat yielded in the production of the iron sulphide FeS. The former is therefore the more stable, while MM. Troost and Hautefeuille have further shown that there appears to be present in pig iron an iron sulphide, which is formed with absorption of heat, and therefore unstable in character. In the combustion of iron silicide in a Bessemer converter, the oxygen is derived from the reduction of the oxide Fe_2O_3 to FeO, and since we have seen that iron silicide is a body of very unstable character, the heat of combustion of it to SiO_2 and FeO is greater than the amount of heat absorbed in the decomposition of the three molecules of Fe_2O_3 to $9FeO + O_2$, which is necessary to supply the oxygen required by the change.

Pourcel has further shown that the thermo-chemical data for the phosphide and carbides of iron, as deter-

mined by Troost and Hautefeuille, are sufficient to explain the fact that "it is perfectly possible to eliminate the carbon and the phosphorus simultaneously in the presence of an alkaline base or lime." In the acid converter, the phosphide of iron cannot be oxidized, since, then, the algebraical sum of the heat units of the materials present is negative. He concludes from his investigation that silica cannot decompose phosphide of iron, and that the temperature plays only a subordinate part in the elimination of the phosphorus. Unfortunately the data at present available are insufficient to follow all the chemical changes involved in the formation of steel, and it is also important to recollect that the chemical changes are not the only work which the heat accomplishes. At high temperatures such as are required in these metallurgical operations, dissociation phenomena take place, and the changes of state are accompanied by changes of the specific heat of the materials, in a manner which at present is unexplained by any experimental evidence. Those who have endeavored to show the value of thermo-chemistry in explaining industrial problems have drawn attention to this want of data, and have also pointed out that any conclusions based upon thermal chemistry must be accepted with caution, for the reasons already stated.—*Industries.*

BRIN'S OXYGEN WORKS.

THE last annual meeting of the Society of Chemical Industry was brought to a conclusion by a series of visits which had previously been arranged by the London committee. Not the least interesting part of the day's programme was the visit paid to the works of Brin's Oxygen Company (Limited), Horseferry Road, Westminster. There were more than one hundred members present, and they were received by Mr. Ellice-Clark, chairman of the company, Mr. Henry Sharp, Mr. Elias, and Dr. Leonard Thorne, chemist to the company. Before proceeding on the work of inspection Mr. Ellice-Clark briefly but clearly described the principle of Brin's process, and also referred to the opposition which the company had had to contend with (although successfully), in order to assure consumers of oxygen that what they supply is really made by the barium method. He added that the works are experimental in character. The members then inspected the plant and the method of working it. We have on a former occasion explained the principle of Brin's process, but we may again state that it takes advantage of the fact, first noticed by Boussingault, that, when barium oxide (BaO) is heated to low redness in a current of air, it takes up oxygen, becoming barium dioxide (BaO_2), and at a higher temperature is reconverted into the lower oxide and free oxygen. In working the process on a commercial scale the company has had numerous difficulties to overcome—chiefly in regard to the construction of the apparatus—but as viewed, the process now seems to be as perfect as it can be. The barium is bought in the form of the nitrate, and is converted into the oxide by simply roasting in clay crucibles. After being broken into pieces the size of a walnut, it is ready for the retorts. Obviously when once packed in them it lasts almost for ever, as the only possible loss which it can suffer is from the occasional pounding which it is submitted to, owing to its refusion. Now as to the process itself. The air is drawn in from the outside by means of a pump, and passes through a cylinder filled with quicklime, then through a smaller one filled with caustic soda. These serve to remove from it the moisture, carbonic acid gas, and other chemical, as well as mechanical, impurities of the London air. So purified, the air is forced along to the retorts, but before it gets there it is received into a small vessel which acts as a kind of buffer and moderates the jerky movement caused by the pulsations of the pump into a steady flow, so that the baryta in the retorts is not disturbed. Meanwhile the retorts have been heated up to a temperature of 600° C. Here we may say that there are two retort furnaces at the works. In the one first constructed the retorts are placed horizontally. These are not now used, for their place has been taken by a furnace in which the retorts are placed vertically. Each retort is an iron tube about 8 inches in diameter and 7 feet long. In each one a small air tube passes right down to the bottom, so that the air must pass up through the whole of the baryta, which was impossible in the case of the horizontal retorts. For ten minutes the air is forced into the retorts, then pumping ceases, a valve is opened which allows the nitrogen to escape, the temperature is brought up to 800° C., and a reversal of the pumps serves to draw away the oxygen which the increased temperature dislodges from the baryta. In the course of two hours about 12,000 cubic feet of air are acted upon, and it is evident that the process is practically continuous. The oxygen is stored in ordinary gasometers, from which it is taken as required and compressed into tubes. The members had every opportunity of inspecting all parts of the plant and process and this they took full advantage of. A selection of beverages aerated with oxygen were submitted for tasting, and met with the approval of the company.—*Chemist and Druggist.*

SPONTANEOUS IGNITION.

DR. ROBERT HIRSCH writes on this subject in the *Chemiker Zeitung* as follows: Like explosions in the manufacture of nitroglycerine, fires have at all times haunted the manufacture of aniline. They mostly originated in the manufacture of nitrobenzol, without the cause being ascertained by subsequent investigation. During the last past years more or less destructive explosions and conflagrations have occurred in English factories which, in want of any better explanation, were attributed to workmen smoking tobacco or to the lighting of matches and other exterior causes. Having recently had an occasion to watch a case of spontaneous ignition, I feel bound to communicate my observations.

As is known, the nitrating acid is through an S-shaped tube run into the apparatus which is furnished with a stirrer. By a mistake toluol had been run into the apparatus by the same tube, and a few c. cm. of it had remained in the tube. When now the acid mixture came into contact with the toluol, the liquid in the tube became at once heated and white vapors were evolved. The workman had the laudable pluck to pull out the tube, and in the moment when he threw it away, ignition took place.

Spontaneous ignition can also occur when, purposely or accidentally, the stirring apparatus is stopped while the acid mixture is still flowing into the apparatus. In that case it sinks through the light hydrocarbon without surrendering its nitric acid. If then the stirrer is again put in motion, an exceedingly strong heating of the mixture suddenly takes place, which can increase to ignition. If several apparatus are connected with one another, perhaps by a common outlet pipe for the escaping nitrous acid, ignition and sometimes explosion occurs in all the apparatus.

OXALIC FERMENTATION.

HERR W. ZOPF records the discovery of a remarkable *Saccharomyces*, to which he gives the name *S. Hansenii*, in which the power of producing alcohol is replaced by that of producing oxalic acid. It was cultivated on beerwort gelatine and flesh peptone gelatine, which it softened without liquefying. On beerwort, sugar solutions, mannite, etc., it produces a pellicle which rapidly precipitated. Cultivated on a solid substratum, it produces endogenous spores from 2 to 4 μ in diameter, usually only one, less often two, in each mother cell. Scarcely a trace of alcohol could be detected in the fluids in which this microbe had been cultivated, while, on the other hand, crystals of calcium oxalate were formed, sometimes in very large quantities, in the same way as with other well known producers of oxalic acid, such as *Penicillium* and *Sclerotinia*. The production of crystals of oxalate was obtained from the following carbohydrates, viz., Galactose, grape sugar, cane sugar, milk sugar, and maltose, also from dulcite, glycerine, and mannite. It is possible that the further investigation of this interesting organism may throw light on the so common production of crystals of calcium oxalate in the form of raphides in plants.

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